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THE INFLUENCE OF SOYBEAN OIL MEAL UPON ROUGHAGE DIGESTION IN CATTLE

WISE BURROUGHS AND PAUL GERLAUGH
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PREVIOUS investigations (Burroughs *et al.*, 1945) have shown a substantial and rather uniform feeding value in corncobs when fed to steers both in fattening trials and in digestion experiments. Despite this over-all uniformity in results, a charateristic common to the feedlot work has been a greater apparent utilization of corncobs in the early part of the fattening period as contrasted with poorer utilization during the final period. This variation within a given experiment, along with certain discrepancies noted in corncob utilization by other workers (Otis, 1904; Mumford, 1905; Allison, 1917; Vaughn, 1927; Gerlaugh, 1928; Peters, 1933; Thalman and Cathcart, 1934; Gerlaugh and Rogers, 1936; King, 1938, 1940) suggested the possibility that the utilization of this roughage might be dependent upon specific characteristics of the ration in which corncobs were incorporated. The first characteristic examined was that of protein. A review of the literature showed that no such studies with corncobs had been reported. There are, however, many references to other feeds, usually rations, which show a general depression in dry matter digestibility with low levels of protein feeding. These references have been amply reviewed in most animal nutrition textbooks from that of Kellner (1907) up to the present time Morrison (1936) and Maynard (1947). Recently Watson *et al.* (1947) and Gallup *et al.* (1948) reported upon the influence of protein upon ration digestibility in cattle. Swift *et al.* (1947) reported similar studies with sheep.

The depressing action of low protein rations upon apparent coefficients of digestion of individual nutrients have been shown to be most marked with respect to protein (as much as 50 percent) and least marked with respect to total dry matter (usually not more than 5 percent). Protein depression in such rations doubtless is more apparent than real since fecal metabolic nitrogen is not considered in such measurements. The decrease in the digestibility of dry matter and of non-protein nutrients, on the other hand, may be of real significance in that it may reflect the activities of microorganisms in the digestive processes.

A difference of 5 percent in corncob utilization resulting from differences in the percentage of protein in the ration would not be of sufficient magnitude to account for differences in feedlot trials. Never-the-less, it was felt that greater differences might actually be found since corncobs represent a feed whose protein content (<2 percent) is extremely low.

As a preliminary to experimental work, the utilization of corncobs as

found by different investigators in feedlot trials was tabulated, along with the calculated amount of protein in each ration. These values are presented in table 1.

The computed percentages of protein fed in these rations varied from about 9 to 12 percent. Comparing the experiments within a given age group, the trend suggests a positive relationship between the percentage of protein fed and the efficiency of corncob utilization.

There are objections which can be raised as to the absolute accuracy of the above calculations. At best, such computations are only approximate and of relative value in predicting trends. Both the protein and total digestible nutrient values were calculated based on average figures presented by Morrison (1936). The selection of experiments was limited to feedlot trials in which ground ear corn was compared with shelled corn for beef cattle.

Experimental Data and Discussion

The influence of soybean oil meal upon corncob digestion was experimentally measured in a series of digestion trials in which four rations were employed. Two rations were low in protein (8 percent) and two were high in protein (15 percent). At each of the two levels of protein feeding, one ration contained corncobs while the second ration contained no corncobs. The ingredients of the rations and the amounts fed are listed in table 2.

TABLE 1. COMPUTED PERCENT RATION PROTEIN AND ESTIMATED CORNCOB UTILIZATION USING DATA FROM LITERATURE

Source of data	Age of steers	Est. % protein in cob ration	Est. T.D.N. value of corncobs
Vaughn, H. W. (1927) 4 trials	Calves	11.3	24
Gerlaugh, P. *et al.* (1936) 3 trials		11.6	24
King, F. G. (1940) 2 trials		11.7	36
Peters, W. H. (1938) 1 trial		11.9	46
Thalman, R. R. *et al.* (1934) 2 trials	Yearlings	9.2	16
Gerlaugh, P. *et al.* (1936) 2 trials		10.4	30
King, F. G. (1938) 1 trial		11.1	53
Allison, H. O. (1917) 3 trials	2 years	11.2	8
Mumford, H. W. (1905) 2 trials		11.9	64

The total amount of daily feed was approximately equal on all rations. This amount was readily consumed and promoted weight gains in 700 lb. Hereford steers. Soybean oil meal was substituted for corn in altering the protein content of the rations. The hay was equalized between rations at a given protein level on the basis of the hay/corn ratio.

TABLE 2. THE EFFECT ON SOYBEAN OIL MEAL (PROTEIN) ON THE DIGESTION OF DRY MATTER IN CORNCOBS AND TIMOTHY HAY

Description feed and animals	Ration number			
	1	2	3	4
	Low Protein		High Protein	
	No cob	With cob	No cob	With cob
Daily feed per steer (lbs.)				
Corn (ground shelled)	7.22	6.00	4.82	3.70
Soybean oil meal	—	0.38	2.42	2.86
Corn-cobs (ground)	—	2.00	—	2.00
Timothy hay (chopped)	4.22	3.50	4.20	3.22
Mineral mixtures*	0.10	0.10	0.10	0.10
Total ration	11.54	11.89	11.54	11.88
Apparent digestion coefficient of corn-cob dry matter				
Steer 15, period a	66.7		70.0	
b	53.7		57.4	
Steer 16, period a	60.6		68.9	
b	53.2		67.0	
Steer 17, period a	54.6		60.1	
b	48.3		61.2	
Steer 18, period a	71.6		76.7	
b	62.4		72.5	
Average	58.9		66.7	
Apparent digestion coefficient of timothy hay dry matter				
Steer 15, period a	37.6	46.9	50.2	61.4
b	48.0	49.8	51.8	54.9
Steer 16, period a	58.2	62.3	60.8	71.3
b	60.7	62.3	57.1	66.2
Steer 17, period a	44.0	46.0	56.9	61.8
b	54.3	53.1	61.3	66.8
Steer 18, period a	38.7	50.9	48.8	64.3
b	45.9	52.6	50.1	62.5
Average	50.7		59.1	

* Mineral mixture contained 2 parts bone meal, 2 parts feeding limestone and 1 part salt.

Corncob digestion at each protein level was determined by the subtraction method. The digestibility of the non-cob fraction of the corncob ration was assumed to be equal to the digestibility obtained in the comparable ration containing no corncobs. Fourteen-day collection periods were used with preliminary adjustment periods of fourteen days or longer on a given

ration. The schedule of feeding the four rations was staggered over the four collections periods so that each ration was fed to one steer in each period.

The coefficients of digestion of the corncob dry matter (table 2) were consistently higher (average 66.7) than the corresponding values in the low protein ration (average 58.9). The variation between steers was rather large. Some variations were also noted in comparing the performance of a given steer in the A period with that of the B period. These two periods represented two different series of trials using the same feeds with the exception of different supplies of soybean oil meal.

The utilization of timothy hay at the two levels of protein feeding was estimated by subtracting the sum of the individual values (Morrison, 1936) of the non-hay ration ingredients from the determined total digestibility of a given ration. The absolute accuracy of this determination is subject to error, however, since similar constants were used for the non-hay feeds in both the high- and the low-protein rations, the relative significance of the hay values appear valid.

The difference observed in hay dry matter digestion (50.7 and 59.1 percent) at the low and high protein levels is of the same magnitude as the difference observed in corncob digestion.

Discussion

Practical significance can be attached to the improvement in roughage digestion resulting from the addition of soybean oil meal to a low protein fattening cattle ration. An improvement of 8 (66.7 less 58.9) absolute percentage in the apparent digestibility of corncobs would suggest a maximum improvement of 14 percent in the over-all feeding value of this roughage. Likewise an improvement of 8 (59.1 less 50.7) absolute percentage in the apparent digestibility of timothy hay would represent a maximum improvement of 17 percent in this roughage.

Whether similar or greater differences might have been encountered if less or more soybean oil meal had been fed cannot be predicted. Neither can one be certain that the differences observed are the direct result of the protein contained in the soybean oil meal. The possibility exists that soybean oil meal might have contributed some beneficial nutritional property to the ration other than protein.

The over-all results of this study suggest that protein supplement probably played a part in some of the divergent results obtained by other investigators in past feedlot trials on the value of corncobs. A maximum difference of 14 percent in cob utilization due to soybean oil meal would also suggest that factors other than ration protein played a part in such divergent results if protein is the active factor in soybean oil meal influencing roughage

digestion. If some other property of soybean oil meal is responsible for improving roughage utilization, then predictions of their total influences is most difficult if not impossible to make at this time.

Summary

The influence of soybean oil meal upon corncob and timothy hay dry matter digestion was studied using steers fed fattening cattle rations. Four rations were used, one with and one without corncobs at an 8 percent protein level, and one ration with and one without corncobs at a 15 percent protein level. Four steers received each ration in two series of trials.

The dry matter digestion in corncobs and timothy hay was increased by 14 percent and 17 percent respectively, by the inclusion of soybean oil meal in the ration. These differences are of practical significance. In the case of corncobs, the beneficial influence of soybean oil meal was not sufficiently great to fully explain the divergent feedlot results on the value of cobs obtained by different investigators. It is possible that factors other than protein may have been responsible for the favorable influence of soybean oil mea upon corncob and timothy hay dry matter digestion.

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FURTHER OBSERVATIONS ON THE EFFECT OF PROTEIN UPON ROUGHAGE DIGESTION IN CATTLE

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A PREVIOUS study by Burroughs and Gerlaugh (1948) indicated that the addition of soybean oil meal to a low protein cattle ration resulted in improved digestability of both corncobs and timothy hay. Similar improvements in digestibility, following the more liberal feeding of protein supplements to ruminants, have been observed by others, reviewed by Kellner (1907) and later by Morrison (1936). Recently Watson *et al.* (1947), Swift *et al.* (1947) and Gallup and Briggs (1948) have reported upon the influence of protein upon digestibility in ruminants.

Explanation of the reasons why protein influences digestion have varied considerably from time to time. The more common current explanation is that the decrease in protein digestibility in low protein rations is more apparent than real because fecal metabolic nitrogen is not taken into account. Conversely, decreases in the digestibility of non-protein nutrients in these same rations may have real significance in that it may involve an impairment in the digestive functions of microorganisms living within the rumen and digestive tract. Whether protein *per se* or other properties of protein supplements are of major importance in stimulating the digestive activities of these microorganisms is not known.

The present paper includes the results of several digestion trials designed to obtain further information on factors in protein feeds which influence roughage digestion in cattle with particular emphasis on corncob utilization.

Experimental Data and Discussion

The choice of experimental methods required much consideration. The most direct method of studying microorganism digestion of roughages in ruminants would involve studies within the rumen. Hale *et al.* (1947) described a lignin ratio method for studying rumen digestion and this method, although helpful to a better understanding of rumen digestion, lacks precision is measuring small differences and is subject to unavoidable limitations in application and interpretation of results. Similar limitations exist in the method of this laboratory (Burroughs *et al.*, 1946) involving the relative rates of passage of different nutrients through the rumen. Another rumen digestion method, namely, the placing of feeds in silk bags inserted in the paunch, McAnally (1942) has met with limited success (unpublished work of the Ohio Agric. Expt. Sta.)

Total digestion experiments appeared most promising in measuring fac-

tors influencing the digestion of roughages by microorganisms, provided certain difficulties could be minimized. Foremost of these difficulties involves interpretation of associative feed influences when one or more feeds are fed with a given roughage. Differences in digestibility of two feeds when fed separately as compared with their digestibility when fed together can be interpreted entirely on the basis of one or the other feed or the difference can be divided between the two feeds. The total digestion method finally adopted minimizes this difficulty by feeding a sizable amount of roughage and then adding certain feeds whose digestibility are known to approach 100.

In the present study, it was planned to use casein additions in studying the influence of protein upon roughage digestion. Considerable difficulty

TABLE 1. RATIONS FED TO DETERMINE FECAL RESIDUE FOR MINERALIZED STARCH AND DRIED SKIMMILK (POUNDS PER STEER DAILY)

Constituents of ration	Ration no. and percent of protein in ration							
	5, 13.5	6, 18.5	7, 16.3	8, 14.6	9, 11.0	10, 9.0	11, 7.7	12, 20.3
Alfalfa hay (chopped)	—	—	—	5.0	5.0	5.0	5.0	5.0
Corncob (ground)	5.0	5.0	5.0	—	—	—	—	—
Starch (mineralized)	1.5	—	1.5	—	2.0	4.0	6.0	—
Dried skimmilk	3.5	5.0	5.0	—	—	—	—	—
Total	10.0*	10.0*	11.0*	5.0*	7.0*	9.0*	11.0*	5.0*

* Each steer also received daily 0.1 lb. iodized salt and 10 ml. of A and D feeding oil (400 i.u vitamin D and 4000 i.u. of vitamin A per gram).

was experienced in getting cattle to consume casein, especially when incorporated in corncob rations. Dried skimmilk made such rations readily acceptable to the cattle and it was used in place of casein.

Corn starch was substituted for skimmilk in certain ration series in order to maintain a constant level of total feed intake. Ten percent bonemeal was added to the starch so that the total mineral content of the mixture approximated that of dried skimmilk (spray process).

Neither dried skimmilk nor mineralized corn starch are 100 percent digestible. Accordingly, the undigestible fraction in both feeds was determined so that corrections could later be made in determining roughage digestion. The rations used (table 1) consisted of one series using corncobs as the sole roughage and one series containing alfalfa hay. Each series was selected at protein levels in which preliminary experiments indicated no associative

influences between the roughage and the starch and none between the roughage and the dried skimmilk. Table 2 summarizes the apparent undigestible dry matter of mineralized starch (average 12.8) and dried skimmilk (average 10.3).

Both the above feeds are high in mineral content, about 8 per cent. It was conceivable that variable absorption of this mineral matter would influence corrections and might jeopardize the significance of dry matter as an index

TABLE 2. APPARENT UNDIGESTIBLE DRY MATTER IN DRIED SKIMMILK AND MINERALIZED STARCH (PERCENT BASED UPON AIR DRY WEIGHT)

Method of determination	Steer No.					
	21	22	23	24	30	Average
Apparent percent undigestible dry matter in mineralized starch						
Ration 7 less ration 6	16.2	15.9	16.3	−5.5	—	10.7
Ration 9 less ration 6	17.8	—	11.8	12.0	7.8	12.4
Ration 10 less ration 8	15.2	—	11.1	20.1	11.4	14.4
Ration 11 less ration 8	15.0	—	12.3	13.0	15.1	13.8
Average for mineralized starch						12.8
Apparent percent undigestible dry matter in dried skimmilk						
Ration 7 less ration 5	30.7	−7.2	9.6	11.1	—	11.0
Ration 12 less ration 8	12.9	—	8.8	4.7	11.8	9.6
Average for dried skimmilk						10.3

of digestion of the roughages. Accordingly, corrections were determined on the basis of dry matter, less ash representing the organic material.

The average apparent undigestible organic matter was 8.0 percent for mineralized starch and 5.2 percent for dry skimmilk. These corrections, when later applied to roughage digestion of organic matter, produced results very similar to the results obtained when dry matter corrections were applied to corresponding digestibility of the roughage dry matter. In view of this similarity, corrections for roughage digestibility are reported on the dry matter basis only.

Replacement of Mineralized Starch with Dried Skimmilk upon Corncob Digestion.

Two series of five trials each were conducted to determine what effect the substitution of dried skimmilk for mineralized starch had upon the digestion

TABLE 3. REPLACEMENT OF MINERALIZED STARCH WITH DRIED SKIMMILK UPON CORNCOB DIGESTION

Description feeds and animals	Ration no. and percent protein in ration				
	13, 5.0	14, 7.5	15, 10.0	16, 13.5	17, 18.5
Amounts (lbs.) fed daily to steers 21, 22, 23 and 24					
Corncobs (ground)	5.00	5.00	5.00	5.00	5.00
Starch (mineralized)	4.00	3.25	2.50	1.50	—
Dried skimmilk	1.00	1.75	2.50	3.50	5.00
Total*	10.00	10.00	10.00	10.00	10.00
*Apparent coefficient of digestion of corncob dry matter***					
Steer 21	56.8	59.2	65.4	65.4	58.9
Steer 22	35.2	55.0	55.0	56.8	63.6
Steer 23	53.5	61.9	61.0	63.4	64.8
Steer 24	46.3	52.2	58.9	69.2	63.0
Average	48.0	57.1	60.1	63.5	62.6
Daily rations fed to steers 26, 27, 28 and 29 were 20% less than the amounts fed steers 21, 22, 23 and 24					
Steer 26	28.4	35.5	32.3	29.0	44.7
Steer 27	49.7	43.4	37.1	52.4	47.9
Steer 28	36.5	38.8	33.7	36.6	47.1
Steer 29	21.6	31.0	37.3	39.2	40.7
Average	34.0	37.2	35.1	39.3	45.1

* Each steer also received daily 0.1 lb. iodized salt and 10 ml. of A and D feeding oil (400 D and 4000 A per gm.).
** Corrections made for fecal residues from starch and skimmilk.

of corncobs. The rations (table 3) in each series were approximately isocaloric containing 50 percent roughage and 50 percent of a mixture of dried skimmilk and mineralized starchl The protein content of the rations varied from 5 to 18.5 percent. It was planned to extend this range to a 2 percent protein level by including a sixth ration made up of equal parts corncobs and mineralized starch. Such a ration was rejected by the cattle and no measurements of digestibility could be made.

The results of both series are presented in table 3. The average apparent digestibility of the corncobs in the first series (steers 21–24) increased from 48.0 to 63.5 percent with increases in dried skimmilk up to the 13.5 percent protein level. No further increase in digestion was noted between the 13.5 and 18.5 percent protein rations. The second series (steers 26–29) also showed an average increase in corncob digestion from 34.0 to 45.1 per-

cent between the lowest (5 percent) and highest (18.5 percent) protein rations.

Although there was general agreement between the two series there were certain differences worthy of consideration. With steers 21–24, roughage digestion was increased at lower protein levels, between 5 and 13.5 percent, whereas in the second series the increase in digestibility took place at a higher protein range, 10 and 18.5 percent. Another difference in the two sets of trials is the consistently higher coefficients of digestion for corncobs in the first series as contrasted with the lower values in the second series.

The reasons for these differences are not known. Different animals and different supplies of feeds were used in the two series but these variables do not offer a tangible explanation. The total daily ration fed in the second series was 20 percent less than that fed in the first series; however, the steers were correspondingly smaller in size, averaging 550 pounds compared to 700 pounds live weight. Another difference was the order in which the rations were fed. In the first series, the rations were fed in the order of their protein content, starting with the lowest protein ration. In the second series the high protein ration was first fed followed in order by each ration with a lower protein content. It is conceivable that the order of feeding might be of major importance if insufficient time was allowed for animals to become adjusted to a new ration before collections began.

In all cases, the adjustment period was approximately 10 days. If one were to assume that this adjustment period was not long enough then the response obtained in the first series in which the protein level was progressively increased would be expected to result in smaller differences in digestibility due to skimmilk additions than were actually found. Furthermore, if the adjustment period was not long enough, one would have expected that corncob digestion would have remained high, "plateauing" over a longer range in the high protein levels, in the second series than was observed in the first series. Actually the reverse was true suggesting that the differences observed in the two series of trials was probably not the result of insufficient adjustment periods.

In view of no obvious explanation for the differences observed in the two series, it can be postulated that factor(s) other than total protein content of the rations may have played a part in influencing roughage digestion. In the second group of cattle, no improvement in corncob digestibility occurred between the 5, 7.5 and 10 percent protein levels. The increase in digestibility occurred only between the 10 and 18.5 percent protein rations. If protein were the first limiting factor in this series of rations for roughage digesting microorganisms, one would expect the protein response at the lower protein levels.

The Replacement of Mineralized Starch with Dried Skimmilk on Clover Hay Digestion.

Clover hay digestibility was studied by feeding this roughage along with variable amounts of dried skimmilk and mineralized starch similar to the methods employed in the corncob studies. The red clover hay was somewhat stemmy, containing 10.3 percent protein. The rations (table 4) varied in protein content from 6 to 18 percent. Ten-day collection periods with ten-day preliminary periods were used throughout, beginning with the low-protein and ending with the high-protein ration.

The results (table 4) show a small but consistent improvement in clover hay digestibility (average 51.2, 53.8 and 56.4) with each increase in protein content of the ration from 6 to 12 percent. No increase in apparent digestible dry matter was obtained with further increase in protein levels. These results suggest that the limiting factor(s) in the low protein clover hay rations was supplied by dried skimmilk. There is some reason to believe that the factor may be the quantity of protein. The improvements in clover hay digestibility reached a maximum at a protein level between 9 and 12 percent which was similar to the effective protein level in the first series with corncobs (between 10 and 13½ percent, table 3). The corncob rations at these protein levels contained more dried skimmilk than the clover hay rations due to the wide differences in the protein content of the two roughages.

TABLE 4. THE REPLACEMENT OF MINERALIZED STARCH WITH DRIED SKIMMILK ON CLOVER HAY DIGESTION

Description feeds and animals	Ration no. and percent protein in ration				
	18, 6.0	19, 9.0	20, 12.0	21, 14.5	22, 18.0
Amounts (lbs.) fed daily to steers 21, 22, 23 and 24					
Clover hay (chopped)	5.00	5.00	5.00	5.00	5.00
Starch (10% bonemeal)	5.00	4.00	3.25	2.50	1.50
Dried skimmilk	—	1.00	1.75	2.50	3.50
Total*	10.00	10.00	10.00	10.00	10.00
*Apparent coefficient of digestion of hay dry matter***					
Steer 21	53.5	54.8	55.4	52.8	54.5
Steer 22	48.4	52.2	58.3	54.0	55.3
Steer 23	57.5	58.0	59.2	58.5	55.7
Steer 24	45.4	50.1	52.6	55.9	56.1
Average	51.2	53.8	56.4	55.3	55.4

* Each steer also received daily 0.1 lb. iodized salt and 10 ml. of A and D feeding oil (400 D and 4000 A per gm.).
** Correction made for fecal residues from starch and skimmilk.

TABLE 5. CORNCOB DIGESTION WITH DRIED SKIMMILK ADDITIONS USING NO STARCH

Description feeds and animals	Ration no. and percent protein in ration		
	23, 4.0	24, 12.0	25, 18.0
Amounts (lbs.) fed daily to steers 21, 22, 23 and 24			
Corncobs (ground)	5.00	5.00	5.00
Dried skimmilk	0.50	2.50	5.00
Total*	5.50	7.50	10.00
*Apparent coefficient of digestion of corn-cob dry matter***			
Steer 21	56.0	59.3	58.9
Steer 22	61.6	60.1	63.6
Steer 23	64.0	58.8	64.8
Steer 24	57.6	57.3	63.0
Average	59.8	58.9	62.6

* Each steer also received daily 0.1 lb. iodized salt and 10 ml. ofA and D feeding oil (400 D and 4000 A per gm.).
** Corrections made for fecal residues from dried skimmilk.

Corncob Digestion with Dried Skimmilk Additions using no Starch.

The influence of dried skimmilk upon roughage digestion in previous trials was measured by substituting the milk for equivalent amounts of mineralized starch. This technique was desirable in order to maintain a constant daily food intake between retions. It is not known whether the favorable influences noted in case of dried skimmilk were due to factor(s) in the milk or to a decrease in the total starch content of the rations. The next experiment was designed to obtain information on these points. The first ration (table 5) contained 5 pounds of corncobs and the least amount of dried skimmilk (one-half pound) which would result in the ready consumption of the roughage. The next two rations contained the same amount of corncobs and 2.5 and 5 pounds of dried skimmilk per steer per day, respectively. The protein of the rations varied from 4 to 18 percent. The adjustment and collection periods were 10 days each, similar to those in earlier series.

Contrary to previous results almost no differences (table 5) were found in corncob digestibility between the low and the high protein levels when starch was left out of the ration. At all protein levels digestibility was uniformly high and quite satisfactory.

The reconciliation of these results with earlier trials raised two possibilities. One might assume that the earlier observations which showed improved

digestibility with dried skimmilk additions were apparent rather than real and that the withdrawal of starch was in reality the influential factor in these trials. Another possibility was that the dried skimmilk additions were helpful to roughage digestion in rations containing starch and that such additions were not helpful when starch was omitted from the ration.

Corncob Digestion with Dried Skimmilk Additions using Constant Amount of Starch.

The next series of trials (table 6) included the feeding of a basal ration containing corncobs (5 pounds) and a liberal amount of starch (4 pounds) with the minimal amount of milk (1 pound) necessary to insure consumption of the ration. This basal ration was compared with two additional rations containing the basal ration feeds and 2 and 3 pounds of dried skimmilk respectively. The total protein in these rations varied from 5.5 to 10.5 percent. It was planned to use a fourth ration containing 4 pounds of dried skimmilk but this ration was refused by the steers. Ten-day collection periods were preceded by adjustment periods of 10 days or longer on each ration.

TABLE 6. CORNCOB DIGESTION WITH DRIED SKIMMILK ADDITIONS USING A CONSTANT AMOUNT STARCH

Description feeds and animals	Ration no. and percent protein in ration		
	26, 5.5	27, 8.0	28, 10.5
Amounts (lbs) fed daily to steers 21, 23 and 24			
Corncobs (ground)	5.00	5.00	5.00
Starch (mineralized)	4.00	4.00	4.00
Dried skimmilk	1.00	2.00	3.00
Total*	10.00	11.00	12.00
*Apparent coefficient digestion corncob dry matter***			
Steer 21	45.8	53.3	52.9
Steer 23	37.0	43.8	41.9
Steer 24	33.8	41.4	40.1
Average	38.9	46.2	45.0

* Each steer also received daily 0.1 lb. iodized salt and 10 ml. of A and D feeding oil (400 D and 4000 A per gm.).
** Corrections made for fecal residues from mineralized starch and dried skimmilk.

The digestibility of corncobs (table 6) in the basal ration was low, averaging 38.9 percent. Increasing the dried skimmilk in the daily ration to 2.0 pounds increased corncob digestion to 46.2 percent. No further improve-

ment in corncob digestion was noted when the dried skimmilk in the daily ration was increased to 3.0 pounds. The results suggest that the addition of dried skimmilk to low-protein rations containing starch is of real significance in improving roughage digestion even though such additions are not effective in rations containing no starch. The failure to increase the digestion of the corncobs beyond 46 percent with additional amounts of dried skimmilk (ration 27 and 28, table 6) again suggests that factors in these rations other than protein may be influential in roughage digestion.

Discussion

Protein fed to cattle and other ruminants presumably serves two separate physiological functions. One function pertains to the growth and development of microorganisms in the digestive tract in fostering roughage digestion and the synthesis of B-vitamins and amino acids. The other function relates to growth in the ruminant's body proper. The total minimum protein requirement of cattle for maximum production thus depends upon which functional need for protein is greatest, since the same feed protein is used in both functions. The problem of determining which functional need is greatest is difficult because the protein requirement for both functions is variable under different conditions. For example, in growing and fattening cattle the protein requirement for growth of body tissues decreases as the animal becomes older. Also in these same animals, as the fattening period progresses, the ratio of starchy feeds to roughage consumption often increases which in turn increases the protein requirement for roughage digestion.

In the present studies no estimate could be made of the range in protein requirements necessary for maintaining efficient roughage digestion under all feeding conditions. The results summarized in table 5, however, indicate that when *corncobs are fed in the absence of starch*, the protein requirement for efficient utilization of this roughage is very low possibly as little as 4 percent in the ration. Such a low level would seldom be encountered in practical feeding operations since most roughages contain a higher protein content and the body protein needs of all ruminants would exceed this amount.

The feeding of rations containing grain in addition to roughage may result in levels of protein sufficient to meet body protein needs, yet such rations may not be high enough in protein to maintain efficient roughage utilization. Fattening cattle, especially older animals, would be most affected by this type of protein deficiency.

It would be desirable to know the minimum protein needed to maintain efficient roughage utilization in heavy grain fattening rations. The present studies tentatively suggest that this minimum level falls between 8 and 12

percent protein. There are many reasons why more information is needed before this level can be estimated with any degree of accuracy. Foremost of these is the lack of understanding of the exact role of starch in increasing the protein requirements in roughage digestion. Also it is not clear whether or not the beneficial influence of protein supplements in maintaining roughage digestion can be attributed entirely to protein *per se*.

Summary

Five series of digestion trials were conducted to study the influence of protein upon roughage digestion in cattle. Protein levels were varied by substituting dried skimmilk for mineralized starch in three series. In two of the three series corncobs were fed as the sole roughage and in the third series clover hay was fed. In the fourth and fifth series, ration protein was varied by adding skimmilk powder directly to corncobs in one instance, and to a constant mixture of corncobs and starch in the other.

Improvement in roughage digestion occurred in every series with dried skimmilk additions where starch formed a part of the ration. Little or no improvement in corncob digestion was noted with dried skimmilk additions when no starch was fed.

The conclusion seems apparent that the protein requirement for efficient roughage digestion in cattle is extremely low when roughages are fed in the absence of starch or starchy grains. When starch forms a part of the ration the need for protein supplement, dried skimmilk, is increased in maintaining roughage digestion. Further study is needed as to the exact method by which starch increases the protein supplement needs for efficient roughage digestion in ruminants.

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SOME DIFFICULTIES INVOLVED IN THE USE OF FECAL NITROGEN AS A MEASURE OF DRY MATTER INTAKE OF GRAZING ANIMALS[1]

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Gallup and Briggs (1948) have suggested that total fecal nitrogen output might be used to calculate the dry-matter intake of grazing steers. The bases for their suggestion were: (1) The observation that in their experiments on the digestibility of prairie hay, fecal nitrogen excretion per 100 grams of dry-matter intake was relatively constant. When the protein content of the hay fed varied from 3 to 6%, the fecal nitrogen excretion per 100 grams of dry matter intake varied from .48 to .61 grams. (2) When a protein supplement was added to the hay, fecal nitrogen excretion increased regularly up to .86 grams per 100 grams dry-matter intake as the protein content of the ration increased to 13%, although there was slight change from an average of .71 grams as the protein varied from 6.22 to 12.0%. (3) Calculations from Morrison's tables showed total fecal output of nitrogen to be constant (.71 grams per 100 grams dry-matter intake) from animals consuming alfalfa hay with protein content varying from 12 to 16%. (4) Calculations based on a summary by Mitchell of Morrison's data indicated that feeding of roughages as a class resulted in an excretion of .67 grams of fecal nitrogen per 100 grams of dry-matter intake when the protein content of the roughage varied from 8 to 16% and of .76 grams of fecal nitrogen when the protein content varied from 16 to 24%.

Experiments recently conducted at this station (Forbes and Garrigus, 1948) lend themselves well to a test of the hypothesis of Gallup and Briggs as applied to grass in grazing stages of maturity. A series of seven digestion trials was conducted, throughout which grade Hereford steers received a constant amount of the dry matter of freshly clipped Kentucky bluegrass as their sole feed. A total of six animals were used, being alternated in groups of three between the trials. Six pounds of dry matter were fed daily in two equal amounts. Table 1 summarizes the results applicable to this part of the study. Each figure in the table represents the average of results for three animals.

There is no apparent constancy to be found in these data in the fecal nitrogen output per 100 grams of dry-matter intake, nor is there a consistent variation between the fecal nitrogen output and the percentage of protein in the feed when these data are considered as a whole. Among the steers

[1] The investigation reported in this paper is in connection with a project of the Kentucky Agricultural Experiment Station and is published by permission of the Director.

TABLE 1. FECAL NITROGEN OUTPUT BY STEERS CONSUMING CONSTANT DRY MATTER OF BLUEGRASS VARYING IN PROTEIN CONTENT

Trial	Group	Protein in forage (%, d.b.)	Lignin in forage (%, d.b.)	Fecal N output (gm./100 gm. dry matter intake)
1	a	19.2	3.9	.711
3	a	16.2	6.0	.667
2	b	14.3	6.9	.661
5	a	12.9	9.1	.767
4	b	12.4	7.1	.698
6	b	11.8	7.9	.714
7	a	11.7	9.0	.827

individually, an apparent trend toward higher nitrogen excretion on the lower plane of protein intake may be seen (figure 1). This may be ascribed logically to a decrease in protein digestibility due to the increasing maturity of the forage, as indicated by the increase of lignin percentage, and to an increase in metabolic nitrogen due to the greater bulk of undigested feed residue on the less digestible, lower protein forages. The daily dry-matter output in these experiments more than doubled as the lignin content of the forage increased from 3.9 to 9.1% although the dry-matter intake remained constant.

The data of Gallup and Briggs indicate an increase in fecal nitrogen per 100 grams of dry-matter intake as the protein percentage of the ration is increased, as shown in figure 1. Our data exhibit a tendency in the opposite direction. This difference in behavior may be explained in part by the fact that the previous data have been obtained on hays whose digestible nutrient contents varied to a relatively small extent as compared with the variation in digestible nutrients of the fresh bluegrass used in our trials. In our experiments the protein digestibility of the forage decreased at nearly the same rate as did the total digestible nutrient content, but in the experiments of Gallup and Briggs the protein digestibility decreased much more rapidly than did the total digestible nutrient content (figure 2). Since the metabolic nitrogen may make up the major portion of fecal nitrogen and on a constant dry-matter intake would vary with the undigested residue of the feed, it is to be expected that total fecal nitrogen excretion would vary, rather than remain constant, as the protein percentage and digestibility of the ration varied.

Calculations from the data presented by Schneider (1947) on the digestibility of alfalfa hays by cattle demonstrate a steady increase in nitrogen output per 100 grams of dry-matter intake as the protein of the hay increased (figure 1). There is no evidence of a constant level of nitrogen excretion that

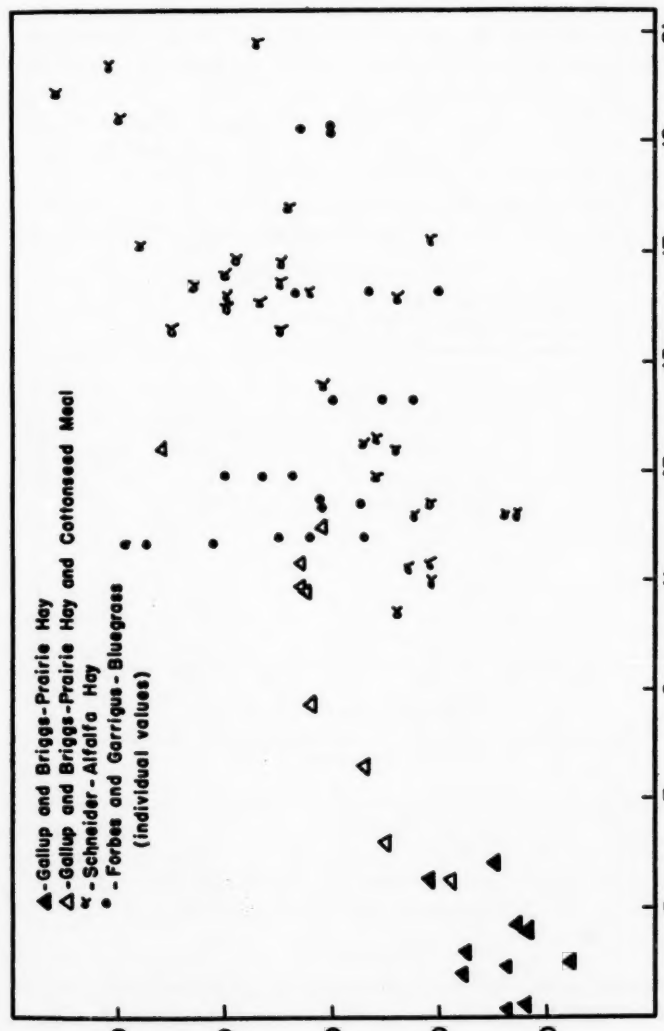

Figure 1. Relationship between protein content of the feed and the nitrogen excretion.

might lend itself to use as an index of dry-matter intake. The nitrogen excretion, calculated from Schneider's data, varies from .53 to .96 grams per 100 grams dry-matter intake as the protein of the forage increases from 10.6 to 20.8%, as shown in figure 1.

The data of Gallup and Briggs and of Schneider indicate that, rather than to assume a constant total fecal nitrogen output per 100 grams of dry-matter intake with varying protein percentage in the forage, it would be better to establish a regression equation expressing the correlation between these two factors. However, our data and those of Schneider indicate the great likeli-

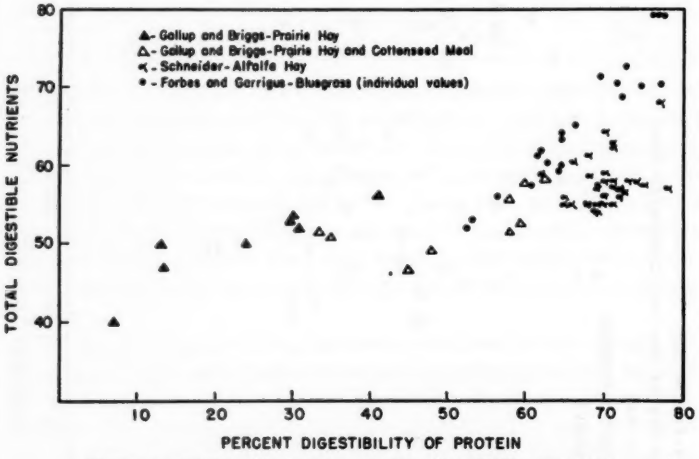

Figure 2. Relationship between protein digestibility and total digestible nutrient content of feeds.

hood of error that might well result from the application of such average figures to individual animals. For the determination of the dry-matter intake of grazing animals, the use of an indigestible "tracer," such as lignin appears to be (Forbes and Garrigus, 1948), is a logical method which promises to be more accurate than the method suggested by Gallup and Briggs.

Summary

Various factors are discussed, emphasizing the difficulties involved in the use of fecal nitrogen excretion as an index of dry-matter intake of grazing animals. On dried roughages, there is a steady increase in fecal nitrogen excretion per 100 grams of dry matter intake as the protein content of the ration increases. On fresh grass, data are too scanty to warrant definite conclusions beyond the fact that the total fecal nitrogen varies too widely to be of practical use in the manner suggested by Gallup and Briggs.

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THE VALUE OF UREA IN PROTEIN SUPPLEMENTS FOR CATTLE AND SHEEP[1]

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A GREAT amount of interest has been shown in the results of feed lot tests with pelleted urea feeds (Stephens *et al.*, 1948) and several important papers on the subject of urea utilization by ruminants have recently been published (Hamilton *et al.*, 1948; Lofgreen *et al.*, 1947; Bowstead and Fredeen, 1948).

In two earlier studies (Briggs *et al.*, 1947, 1948) the value of urea nitrogen in pelleted protein supplements containing increasing amounts of urea were compared with cottonseed meal for cattle and sheep. Urea replaced different amounts of cottonseed meal in the pellets so as to supply 25 percent, 50 percent, 75 percent and nearly 100 percent of the total nitrogen in different pellets. The other constituents of the pellets were hominy feed and blackstrap molasses. All pellets contained about the same amount of total nitrogen equivalent to about 45 percent of protein. Pellets in which urea supplied 25 and 50 percent of the total nitrogen, pellets No. 1 and No. 2, respectively, proved the most satisfactory in feed lot trials and permitted nitrogen retention in nitrogen balance trials about equal to that produced by an equivalent amount of protein from cottonseed meal. The results did not permit a comparison of pellet constituents with and without the addition of urea.

The present experiments were designed to determine by more direct means the value of the nitrogen contributed by urea in pellets No. 1 and No. 2. Since it is a common practice to feed protein supplements on alternate days to range cattle, additional nitrogen balance trials were carried out to determine whether or not urea utilization is influenced by frequency of feeding.

Method and Procedure

Nitrogen balance trials were conducted with two-year-old Hereford steers and growing wether lambs receiving maintenance, wintering, and fattening rations. The constituents of the rations and the amounts fed are shown in tables 1 and 2.

[1] A research grant from the E. I. du Pont de Nemours and Company, Inc., has assisted in making this study possible. The urea used in these studies was obtained from "Two-Sixty-Two" Feed Compound, a material containing 91 per cent urea.

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TABLE 1. RATIONS FED TO STEERS (AIR DRY BASIS)

Type of ration	Ration identification	Crude protein (N×6.25)	Supplement N as urea	Daily feed allowance					
				Prairie hay	Corn	Cottonseed meal	Hominy feed	Molasses	Urea
		percent	*percent*	gm.	gm.	gm.	gm.	gm.	gm.
Maintenance	A	7.4	0	4536	0	311	50	45	0
	B	8.4	25	4536	0	311	50	45	18.6
	E	7.6	0	3629	0	227	145	45	0
	F	8.5	50	3629	0	227	145	45	37.2
Wintering	C	11.3	0	4536	0	933	150	135	0
	D	13.9	25	4536	0	933	150	135	56.0
	G	11.8	0	3629	0	681	435	135	0
	H	17.9	50	3629	0	681	435	135	111.6
Fattening	I	10.7	0	1815	3100	390	63	57	0
	J	11.9	25	1815	3100	390	63	57	23.3
	K	10.0	0	1815	3100	284	182	57	0
	L	12.4	50	1815	3100	284	182	57	46.6

TABLE 2. RATIONS FED TO LAMBS (AIR DRY BASIS)

Type of ration	Ration identification	Crude protein (N×6.25)	Supplement N as urea	Daily feed allowance					
				Prairie hay	Corn	Cottonseed meal	Hominy feed	Molasses	Urea
		percent	*percent*	gm.	gm.	gm.	gm.	gm.	gm.
Maintenance	A	7.4	0	636	0	43.5	7.0	6.3	0
	B	8.4	25	636	0	43.5	7.0	6.3	2.60
	E	7.6	0	508	0	31.8	20.3	6.3	0
	F	8.5	50	508	0	31.8	20.3	6.3	5.21
Wintering	C	11.3	0	636	0	131.0	21.0	18.9	0
	D	13.9	25	636	0	131.0	21.0	18.9	7.84
	G	11.8	0	508	0	95.4	60.9	18.9	0
	H	17.9	50	508	0	95.4	60.9	18.9	15.60
Fattening	I	10.7	0	218	372	46.8	7.6	6.8	0
	J	11.9	25	218	372	46.8	7.6	6.8	2.8
	K	10.0	0	218	372	34.1	21.8	6.8	0
	L	12.4	50	218	372	34.1	21.8	6.8	5.6

Maintenance Rations

The maintenance ration for steers was prairie hay and about one pound of protein supplement daily. The supplements in rations A and B were combined in the same proportion as they occur in pellet No. 1 in which 25 percent of the total nitrogen comes from urea. The urea was omitted from ration A and included in ration B. In rations E and F the supplements were fed in the same proportions as they occur in pellet No. 2 in which 50 percent of the total nitrogen comes from urea. Urea was omitted from ration E and included in ration F.

The constituents of the maintenance rations for lambs were the same as those fed steers; they were fed in the same proportion, but the amounts so fed were only 14 percent of the quantity fed steers.

Wintering Rations

The wintering ration for steers was prairie hay and about 3 pounds of protein supplement daily. The supplements fed in rations C and D were in the same proportion as in pellet No. 1 with the urea omitted from ration C. The supplements fed in rations G and H were in the same proportion as in pellet No. 2 with the urea omitted from ration G. Lambs were fed the same rations but only 14 percent of the quantity fed steers. The principal difference between the maintenance and wintering rations was in the quantity of supplement.

Fattening Rations

The fattening rations were made up of prairie hay and corn, the supplements in rations I and J being in the same proportion as pellet No. 1 with urea omitted from ration I. The supplements in K and L corresponded to Pellet No. 2 with urea omitted in ration K. Lambs received the same rations but only 12 percent of the quantity fed steers.

Other Rations Fed

Rations fed to steers to determine the effect of frequency of feeding on nitrogen utilization were composed of prairie hay with supplements of cottonseed meal and pellet No. 1. The supplements were compared when fed twice daily and when fed on alternate days. In other trials, pellet No. 1 was fed twice daily and daily.

Excreta Collections and Analyses

Feces and urine were collected in the same manner as described in previous papers (Briggs *et al.*, 1947–1948). Care was taken to keep the urine acid during collection periods in order to secure data on the urinary excre-

tion of urea and ammonia. In some trials with steers these constituents and creatinine and creatine were determined on daily samples of urine (Dinning, 1948).

Nitrogen was determined on feces samples previous to drying. Feces samples taken directly from the colon of sheep on rations G and H were examined for urea and ammonia-N. Only traces, 0.52 mg. per gram, dry-matter basis, were found present (Dining *et al.*, 1948). There was an unavoidable small contamination of sheep feces by urine during collection periods.

Blood samples were taken at the end of all collection periods approximately 8 hours after the last feeding. Urea-N of the blood, and urea- and ammonia-N of urine were determined according to the method of Van Slyke and Cullen (1914).

Possible losses of ammonia through expired air and regurgitation were checked with the aid of a modified gas mask for horses which directed the expired air through a dilute solution of HCl. Steers soon became accustomed to the mask and no trouble was encountered in using it over 2 hour periods. The mask was placed on steers following the feeding of 6 pounds of urea pellet No. 1 which supplied over 100 gm. of urea. No ammonia was detected in the expired air during the next 2 hours.

Differences in nitrogen retention obtained in the nitrogen balance trials were tested for significance by the t-test (Snedecor, 1947). The probability values so obtained are given with other data in tables 3 and 4. A P value of .05 or lower is usually considered significant.

Results and Discussion

Data taken from the results obtained in nitrogen balance trials with steers on the maintenance, wintering and fattening rations are presented in table 3. The steers refused to eat their full allowance of one of the wintering rations, ration H, which contained 112 gm. of urea. The data secured, therefore, when rations G and H were fed are omitted. There were no feed refusals when any of the other rations were fed. Feed refusals with ration H were apparently due to the high urea content of the ration since ration G was completely consumed.

The average nitrogen retention of steers on each type of ration was increased whenever additional nitrogen was supplied by urea. The differences in nitrogen retention values between rations similar in all respects except for the addition of urea were statistically significant in three of the five comparisons. These significant differences were not confined to the results obtained with one type of ration but were obtained with one each of the maintenance wintering and fattening rations; A vs. B, C vs. D and K vs. L. Failure of urea to improve significantly nitrogen retention in two compari-

TABLE 3. DAILY NITROGEN BALANCE DATA SECURED WITH STEERS

Type of ration	Ration identification	No. of animals	Supplement N as	Nitrogen intake			Nitrogen excretion			N retention	Significance of difference	Percent of urea-N retained	Percent of total N retained	Urea-N in blood
				Total	Less urea N	As urea	In feces, total	In urine—						
								total	as urea +NH_3					
			percent	gm.	gm.	gm.	gm.	gm.	gm.	gm.	*P value*	*percent*	*percent*	Mg. *percent*
Maintenance	A	4	0	53.8	53.0	0	30.2	23.4	11.6	0.2	.02–.01	—	0.1	9.6
	B	4	25	61.6	53.8	7.8	29.5	27.8	13.3	4.2		51.3	6.8	11.8
Wintering	E	6	0	45.9	45.9	0	21.9	21.5	10.2	2.4	.6 –.5		5.2	7.0
	F	6	50	61.5	45.9	15.6	21.5	36.0	23.5	4.0		10.3	6.5	12.5
	C	4	0	95.7	95.7	0	37.8	42.3	25.0	15.6	.02–.01		16.3	12.6
	D	4	25	119.2	95.7	23.5	37.5	59.4	41.7	22.3		28.5	18.7	18.2
Fattening	I	6	0	82.7	82.7	0	36.7	23.6	10.7	22.4	.8 –.7		27.1	6.3
	J	6	25	92.5	82.7	9.8	35.9	32.8	19.9	23.8		14.3	25.7	7.5
	K	6	0	77.4	77.4	0	37.1	20.9	8.8	19.4			25.1	6.8
	L	6	50	97.0	77.4	19.6	35.6	32.7	21.0	28.8	.01	48.0	29.7	8.6

TABLE 4. DAILY NITROGEN BALANCE DATA SECURED WITH LAMBS

Type of ration	Ration identification	No. of animals	Supplement-N as urea	Nitrogen intake			Nitrogen excretion		N retention	Significance of difference	Percent of urea N retained	Percent of total N retained	Urea N in blood
				Total	Less urea N	As urea	In feces total	In urine total					
					percent	gm.	gm.	gm.	gm.		gm.		*Mg. percent*
Maintenance	A	8	0	7.2	7.2	0	3.9	2.8	0.5	.3 −.2		6.9	7.8
	B	8	25	8.3	7.2	1.1	3.9	3.5	0.9		33.4	10.8	8.8
	E	8	0	6.8	6.8	0	3.4	2.1	1.3	.1 −.05		19.1	4.7
	F	8	50	8.0	6.8	2.2	3.4	3.8	1.8		22.7	20.0	7.9
Wintering	C	8	0	13.0	13.0	0	5.0	5.2	2.8	.01		21.5	12.2
	D	8	25	16.3	13.0	3.3	5.1	6.7	4.5		51.5	27.6	17.0
	G	8	0	11.9	11.9	0	4.5	3.8	3.6	.02−.01		30.2	9.9
	H	8	50	18.5	11.9	6.6	4.4	8.5	5.6		30.3	30.3	13.7
Fattening	I	8	0	9.9	9.9	0	4.3	2.4	3.2	.2 −.1		32.3	5.6
	J	8	25	11.1	9.9	1.2	4.5	2.7	3.9		58.3	35.1	7.6
	K	8	0	9.3	9.3	0	4.3	2.3	2.7	.02−.01		29.0	4.0
	L	8	50	11.7	9.3	2.4	4.3	3.2	4.2		62.5	35.9	6.5

sons could not be related to the composition of the rations or the amounts fed.

Urea produced no significant change in fecal nitrogen excretion but produced an increase in total-N of the urine, which was largely in the form of urea and ammonia. Apparently the nitrogen contributed by urea was readily digested from all rations. Low retentions resulted from its poor utilization in metabolism. Blood urea values, which were increased when urea was fed were within the normal range for cattle.

Results obtained in the trials with lambs are given in table 4. There were no feed refusals as occurred with steers when the high-urea ration H was fed. It seems that lambs will tolerate higher percentages of urea in the ration than steers. The amount of nitrogen retained by lambs on all rations was increased by the addition of urea. Increases in retention attributable to urea were of statistical significance in comparisons of both the wintering rations C vs. D. and G. vs. H, in one of two comparisons of the fattening rations, K vs. L; and they approached significance in one of two comparisons of the maintenance rations, E vs. F. In those comparisons in which differences did not approach significance as with rations A and B, and rations I and J, only a small amount of urea nitrogen had been added to the basal ration. The accuracy with which retentions can be measured when such small amounts of nitrogen are added to a ration in balance trials may be subject to question.

Fecal and urinary nitrogen excretions of lambs followed the same pattern as did those of steers. There was no evidence of rumen synthesis of protein from urea that was lower in digestibility than that of the preformed protein in the original ration. Blood urea values were increased by urea. From a consideration of the calculated values for percent of urea nitrogen retained, it is evident that the lambs were more efficient than the steers in making use of urea at the levels of intake studied. The lambs made better use of urea in the fattening trials than in the maintenance trials. The results with steers were inconsistent.

The total amount of nitrogen retained was about the same when urea furnished 50 percent of the supplemental nitrogen as when it furnished 25 percent. This is shown in a comparison of the results obtained with rations B vs. F, D vs. H, and J vs. L. Since the amount of hominy feed was increased in the supplement containing the higher percentage of urea these rations differed with respect to carbohydrates as well as source of nitrogen, and it seems a likely possibility that this increased proportion of carbohydrate feed in the 50 percent urea-nitrogen supplement enhanced nitrogen retention. This sparing effect of carbohydrates is more apparent in the results with maintenance and wintering rations than in those with the fattening rations. It reveals itself also in the results obtained with the non-urea rations.

TABLE 5. THE APPARENT COEFFICIENTS OF DIGESTIBILITY OF NUTRIENTS IN THE MAINTENANCE, WINTERING AND FATTENING RATIONS FED TO STEERS AND LAMBS

Type of ration	Ration identification	Animals	Supplement N as urea	Apparent Digestibility of—				
				Crude protein	Ether extract	Crude fiber	N-free extract	Organic matter
				percent	*percent*	*percent*	*percent*	*percent*
Maintenance	A	Steers	0	43.7	50.5	62.0	58.8	58.5
	B	"	25	52.6	49.6	66.4	63.1	62.5
Wintering	E	"	0	52.3	57.2	70.2	66.5	66.3
	F	"	50	65.0	57.6	71.8	67.3	67.4
Fattening	C	"	0	60.5	65.8	66.5	64.5	64.7
	D	"	25	68.4	65.4	64.5	62.2	61.3
Maintenance	I	"	0	55.7	71.8	57.8	70.5	67.1
	J	"	25	26.0	73.6	60.5	72.7	69.4
Wintering	K	"	0	53.3	70.5	60.0	73.2	69.2
	L	"	50	63.3	72.4	59.1	73.5	69.8
Fattening	A	Lambs	0	46.1	63.7	58.0	58.3	57.2
	B	"	25	52.9	54.4	58.2	59.0	57.6
Maintenance	E	"	0	49.0	58.6	62.9	61.2	60.0
	F	"	50	61.8	58.3	63.3	61.8	61.2
Wintering	C	"	0	61.3	67.9	57.8	60.5	60.4
	D	"	25	68.6	67.1	57.8	60.9	60.2
Fattening	G	"	0	61.6	71.8	60.4	63.2	63.2
	H	"	50	75.7	72.6	62.3	66.0	64.8
Maintenance	I	"	0	57.1	77.4	49.6	79.8	72.9
	J	"	25	59.8	75.9	50.7	80.6	73.2
Wintering	K	"	0	54.9	80.0	47.3	80.0	72.4
	L	"	50	63.5	78.5	50.6	80.6	73.7

Although these comparisons of results are favorable to the use of a pelleted supplement with 50 percent of the nitrogen as urea, in some feeding practices this amount of urea may lower feed consumption as was encountered with ration H fed to steers. For this reason, a 25 percent urea-nitrogen supplement such as pellet No. 1 might prove preferable to the 50 percent supplement at high levels of feed intake over long feeding periods.

The apparent digestibility of nutrients in the maintenance, wintering and fattening rations by steers and lambs are given in table 5. Urea increased the apparent coefficients of digestibility of protein roughly in proportion to the amount added, but had no consistent effect on the digestibility of other nutrients. The results are in substantive agreement with those ob-

TABLE 6. AVERAGE APPARENT DIGESTIBILITY OF NUTRIENTS AND AMOUNT OF NITROGEN STORED BY STEERS FED AT DIFFERENT INTERVALS

Supplement fed with prairie hay	Feeding interval	Average daily feed intake			Nitrogen retained daily	Apparent Digestibility of—				
		Hay	Supplement	Nitrogen		Crude protein N×6.25	Ether extract	Crude fiber	N-free extract	Organic matter
		gm.	gm.	gm.	gm.	*percent*	*percent*	*percent*	*percent*	*percent*
Urea pellet No. 1	Twice daily	4536	1360	122.5	15.7	67.3	67.0	66.1	60.4	63.2
Urea pellet No. 1	Alternate days	4536	1360	123.0	13.1	64.2	65.9	68.3	60.7	63.9
Cottonseed meal	Twice daily	4536	1360	116.2	15.4	60.5	70.9	64.4	58.3	60.6
Cottonseed meal	Alternate days	4536	1360	117.1	15.4	58.1	72.7	63.5	57.8	60.5

tained by Swift *et al.*, (1947) with rations containing adequate protein and energy plus supplements of urea. Steers were more efficient than lambs in the digestion of most ration constituents, especially crude fiber.

Data secured in nitrogen balance and digestibility trials with steers fed supplements of pellet No. 1 and cottonseed meal twice daily and on alternate days are given in table 6. The average daily ration was 10 lbs. of prairie hay and 3 lbs. of supplement. The pellet No. 1 consisted of 4 percent urea, 75 percent cottonseed meal, 10 percent hominy feed, and 11 percent molasses. Although the different intervals of feeding had no effect on the digestibility of the nutrients in either ration, nitrogen retention was slightly higher when the urea pellet was fed twice daily than on alternate days. This difference was not statistically significant. The trials were repeated with the urea pellet being fed twice daily, every day, and every other day in amounts equivalent to 3 pounds daily. Hay intake was variable but averaged about 8 pounds daily. The average daily nitrogen intake, 20 percent of which was furnished by urea, was 112 grams. The daily nitrogen retention values obtained when the pellet was fed twice daily, every day, and every other day were 14.4 grams, 11.7 grams, and 15.8 grams respectively. The differences were not statistically significant.

Summary

Two protein supplements, originally prepared in pellet form for range feeding, were compared in maintenance, wintering and fattening rations fed to steers and lambs in nitrogen balance trials. Urea supplied 25 percent of the total nitrogen in one supplement and 50 percent in the other one. The value of the nitrogen contributed by urea in these supplements was determined by feeding the same supplements, without urea, in identical rations.

Nitrogen retention by steers and lambs on each type of ration was increased by the additional nitrogen supplied by urea in the supplements. The 50 percent urea-nitrogen supplement was as efficient as the 25 percent supplement in promoting these retentions. There were feed refusals by steers, however, when the 50 percent supplement was fed in wintering rations.

Lambs appeared to be more efficient than the steers in utilizing urea nitrogen.

The apparent digestibility of ration nutrients other than protein ($N \times 6.25$) was unaffected by urea. Feeding the 25 percent urea-nitrogen supplement at less frequent intervals, on alternate days as compared to daily and twice daily, had no effect on urea utilization by steers.

No ammonia could be detected in the expired air of steers following the feeding of urea.

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THE INFLUENCE OF TOCOPHEROLS UPON THE MAMMARY AND PLACENTAL TRANSFER OF VITAMIN A IN THE SHEEP, GOAT AND PIG

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IT has recently been shown that tocopherols exert a pronounced vitamin A sparing action in the rat, especially when vitamin A is fed at near minimum levels (Moore, 1940; Hickman *et al.*, 1942, 1944; Harris *et al.*, 1944; Lemley *et al.*, 1947; and others). However, even at higher levels of vitamin A intake there is still some sparing action (Guggenheim, 1944; Moore 1940). Similar studies have not been carried out with farm animals.

In view of this sparing or protective action of tocopherols on vitamin A it was decided to determine whether supplementing the rations of farm animals with vitamin E would increase the mammary and placental transfer of vitamin A. Because of the small liver reserves of vitamin A in most animals at birth it seemed important to learn whether extra vitamin E would facilitate placental transfer to the fetus.

In a previous study at this station, Thomas *et al.* (1947) reported that the newborn kid has only negligible reserves of vitamin A in its liver at birth while the newborn pig has appreciable reserves when the pregnant animals were fed normal rations. The first colostrum of the goat was found to be higher in vitamin A content than that of the sow. Upon supplementing the pregnant doe and sow's ration with vitamin A, significant increases were found both in the liver reserves of vitamin A and in the vitamin A content of first colostrum. Similar studies have shown that the liver storage of vitamin A in the newborn calf, and the vitamin A content of the first colostrum of the cow can be significantly increased by prepartum vitamin A supplementation (Spielman *et al.*, 1946, 1947, and Wise 1946). However, in all of these studies massive doses of vitamin A (approximately 100,000 I. U. of vitamin A per 100 lbs. body weight daily) were fed. In the present test small supplements of vitamin A were compared with normal rations.

Experimental

This study, involving 40 ewes, 13 goats, and 25 sows, was carried out during the spring of 1947. The ewes, goats and sows were each divided into 4 comparable groups. One group of ewes, goats, and sows were fed a basal ration. In the case of the ewes and goats this ration consisted of second-cut alfalfa and clover hay and cull beans (red-kidney). This ration was chosen

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because it is thought to be deficient in tocopherol activity, as evidenced by the fact that a large percentage of the lambs raised by ewes fed this ration develop muscular dystrophy (Willman *et al.*, 1945, 1946). The ration fed the sows was a standard herd ration including 10% alfalfa hay. These rations supplied approximately 28 mg. of carotene daily per 100 lbs. body weight to the ewes and goats and 3 mg. daily per 100 lbs. body weight to the sows. The second, third and fourth groups of ewes, goats, and sows were fed per 100 lbs. body weight daily, 12,000 I. U. of vitamin A, 80 mg. of mixed natural tocopherols, and 12,000 I. U. of vitamin A together with 80 mg. of tocopherols respectively. This level of vitamin A supplementation was approximately one-eighth that fed by Thomas *et al.* (1947), and was chosen so as to ascertain whether lower levels would give as large a storage as the higher levels fed by Thomas *et al.*, and also because tocopherols are known to have a greater sparing action when vitamin A is fed at lower levels. The level of tocopherols fed was near that found to give optimum response in the rat per unit of body weight.

The supplements were fed during the last 6 weeks of pregnancy and were discontinued at parturition. The vitamin A and tocopherols were supplied to the ewes and sows in the form of stabilized dry powdered concentrates[3] which were mixed with the feed once daily just prior to feeding. Vitamin A was supplied to the goats as a concentrate vitamin A fish oil (55,000 I. U. per gram) and tocopherols as mixed natural tocopherols (22%) in corn oil[3] administered orally once weekly.

Samples of liver and blood plasma for vitamin A and carotene analyses were obtained from a few newborn lambs. kids, and pigs that were sacrificed before they had suckled. In addition, livers of pigs that died at birth were also used for analyses. The Vitamin A and carotene content of blood plasma was determined by the method of Kimble (1939) and that of the livers by the method of Davies (1933). A sample of colostrum was obtained from each ewe, sow and goat before the young had suckled, and fourth-day milk samples from most of the ewes and all of the goats. The colostrum and milk samples were analysed for vitamin A and carotene by the method of Boyer *et al.* (1944).

Results and Discussion

Only traces of carotenoid pigments were found in blood plasma, liver and milk samples irrespective of supplementation and are therefore not reported in this paper. Braude *et al.* (1946) found by chromatographic separation that the carotenoid pigments present in sows' milk was not carotene but probably xanthophylls.

[3] Generously supplied by Distillation Products, Inc., Rochester, N. Y.

TABLE 1. THE EFFECT OF VITAMIN A AND TOCOPHEROL SUPPLEMENTATION ON THE BLOOD PLASMA VITAMIN A LEVELS IN SHEEP AND GOATS

Prepartum supplement	Sheep			Goats		
	No. of Cases	Vitamin A		No. of cases	Vitamin A	
		Before	After		Before	After
		μg./100 ml.	μg./100 ml.		μg./100 ml.	μg./100 ml.
None	10	30±5*	30±3	4	37± 4	37± 9
Vitamin A	10	28±3	31±3	4	39± 9	41± 7
Tocopherols	10	28±4	31±6	4	42±13	40±11
Tocopherols & Vit. A	10	30±3	31±5	4	40± 9	41± 9

* Mean and standard deviation.

The vitamin A content of the blood plasma of the pregnant ewe and goat before supplementation and after 4 weeks of supplementation is shown in table 1. As is evident from this table the prepartal supplements did not increase the vitamin A content of the blood plasma of these animals. Spielman *et al.* (1946) found that even when high levels of carotene (1,000,000 I. U. daily) were fed to dairy cows there was a considerable drop in the blood plasma carotene and vitamin A content between the 60th and 18th day preparatum, and only when high levels of vitamin A (1,000,000 I.U. daily)

TABLE 2. THE VITAMIN A STORES IN THE LIVERS AND BLOOD PLASMA OF NEWBORN LAMBS, KIDS AND PIGS

Prepartum supplement	Lambs		Kids		Pigs	
	No. of Cases	Vitamin A	No. of Cases	Vitamin A	No. of Cases	Vitamin A
		Livers (μg./gm.)				
None	4	0.19 (0.16–0.23)*	3	0.30 (0.16–0.40)	4	5.08 (4.64–6.09)
Vitamin A	3	0.58 (0.52–0.63)	2	1.14 (0.91–1.37)	5	26.26 (18.40–33.92)
Tocopherols	3	0.43 (0.28–0.55)	2	0.27 (0.21–0.32)	5	5.23 (3.50–7.30)
Tocopherols and Vitamin A	3	0.57 (0.54–0.68)	2	2.52 (2.06–2.97)	8	18.22 (12.31–27.04)
		Blood Plasma (μg./100 ml.)				
None	3	3.5 (2.1–5.2)*	3	4.2 (3.3–5.6)	2	8.1 (5.3–10.9)
Vitamin A	3	6.2 (4.0–9.0)	2	8.7 (8.1–9.3)	4	8.4 (5.7–11.4)
Tocopherols	3	4.8 (4.0–5.5)	2	1.6 (1.2–2.0)	1	8.1
Tocopherols & Vitamin A	3	4.6 (3.4–5.8)	2	4.8 (3.1–6.6)	6	10.1 (8.3–15.0)

* Figures in parentheses are highest and lowest values observed.

were fed was there a slight increase in the plasma vitamin A content, but this was accompanied by a considerable drop in the plasma carotene content, Thomas *et al.* (1947) found that the vitamin A content of the blood plasma of goats increased practically 2-fold when supplemented with 100,000 I.U. of vitamin A daily during a similar period.

The vitamin A content of the liver tissue of the newborn lamb, kid and pig was increased by prepartum vitamin A supplementation (table 2); however the increases are not as large as those found by Thomas *et al*,

TABLE 3. THE VITAMIN A CONTENT OF THE FIRST COLOSTRUM AND FOURTH-DAY MILK PRODUCED BY EWES, GOATS AND SOWS

Prepartum supplement	Ewes		Goats		Sows	
	No. of cases	Vit. A μg./gm. fat	No. of cases	Vit. A, μg./gm. fat	No. of cases	Vit. A, μg./gn. fat
First Colostrum						
None	10	29 (18–42)*	3	44 (32–60)	5	24 (12–42)
Vitamin A	7	34 (23–54)	2	59 (45–72)	5	39 (22–77)
Tocopherols	7	26 (12–37)	4	44 (15–59)	4	26 (17–53)
Tocopherols & Vit. A	7	36 (26–54)	4	76 (51–99)	6	39 (21–79)
Fourth-day Milk						
None	10	9 (4–18)	3	9 (4–14)	-	—
Vitamin A	8	9 (6–14)	2	8 (7–8)	—	—
Tocopherols	9	10 (5–21)	4	11 (5–18)	—	—
Tocopherols & Vit. A	8	16 (9–22)	4	15 (5–27)	—	—

* Figures in parentheses are the highest and lowest values observed.

(1947) when much greater amounts of vitamin A were fed. Only in the case of the lambs did the addition of tocopherols to the basal ration increase the placental transfer of vitamin A. This increase is statistically significant (5% level of probability). Tocopherols also tended to increase the liver storage of vitamin A in the goat when fed in combination with vitamin A. However, this difference was not statistically significant (5% level of probability).

Prepartum supplementation with vitamin A tended to result in increased plasma vitamin A of the newborn but too few observations were made for these differences to be significant. Apparently, blood plasma vitamin A is a poor index of body stores of this nutrient in the newborn.

Prepartum supplementation increased the vitamin A content of the first colostrum of the ewe, goat, and sow (table 3), however, due to the high

individual variation within each group the increases were not statistically significant. Tocopherol supplementation had no influence on the vitamin A content of the first colostrum, but did tend to increase the vitamin A content of the fourth-day milk of the ewe and goat. However, these increases were not statistically significant. The vitamin A content of the colostrum of the sow is very similar to that of the ewe, while that of the goat is somewhat higher. Fourth-day milk contained approximately one-fourth as much vitamin A as first colostrum.

The average fat percentages in the first colostrum, as determined by the standard Babcock test, produced by the ewes, goats and sows were 11.1, 8.7, and 4.8% respectively, while those of the fourth-day milk of the ewe and goat were 7.0 and 6.0% respectively.

Summary

Supplementing the prepartum ration with 12,000 I.U. of vitamin A daily per 100 lbs. live weight increased the liver stores of vitamin A of the newborn and vitamin A content of the colostrum. Supplementing the prepartum ration with 80 mg. of tocopherols per 100 lbs. live weight increased the liver stores of vitamin A in the newborn lamb but had little effect on the liver storage of vitamin A in the newborn kid and pig. Tocopherol supplementation at the levels fed had no influence on the vitamin A content of the colostrum of the species studied. Tocopherol supplementation in combination with vitamin A had no significant effect on the vitamin A stores of the newborn at birth or on the vitamin A content of colostrum, when compared to those receiving only vitamin A.

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STUDIES OF THE EFFECT OF PHOSPHATE FERTILIZATION ON THE COMPOSITION AND NUTRITIVE VALUE OF CERTAIN FORAGES FOR SHEEP[1,2]

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In recent years fertilizer programs have experienced a shift of emphasis from one on yield only to one including an assessment of nutritive value. In studies of the influence of fertilization on the nutritive value of forage crops, the critical problem becomes one of evaluating the multitude of factors and the variability of their effects in a complex soil-plant-animal relationship. At present, conclusions reached in this field of investigation are in a state of controversy because they are often based on data from inadequately-planned animal experiments.

It has generally been found (Hall *et al.*, 1941; Edwards, 1941; Eheart and Pratt, 1942; Gard *et al.*, 1943; Brown and Munsell, 1943; Sherwood *et al.*, 1947) that yield of forages and, therefore, pounds of total digestible nutrients per acre, have increased with fertilization. The interpretation of these data in terms of the nutritive value of a specific forage species is obscured by the fact that fertilization changes the botanical composition of the hay or pasture. A recent review of the complexity and status of this subject, including a critical appraisal of the work of Albrecht and coworkers (Albrecht and Smith, 1941; Smith and Albrecht, 1942; Hogan *et al.*, 1942; and McLean *et al.*, 1943) has been made by Beeson (1946).

Proper assessment of nutritive value in studies of this kind must include control or measurement of biological variations arising from (a) gradients in soil fertility, (b) differences in forage composition due to the variability in composition of each species as well as variations in the botanical composition of the forage, and (c) differences in animal response. With these factors in mind, a long term experimental plan was designed and initiated in 1945. The data reported here are the results of two lamb-feeding trials followed by digestion trials and determination of nitrogen balances using differentially phosphated crops raised in 1945 and 1946.

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History, Fertilizer Treatment, and Field Layout

The crops were grown on soil described as a Bladen silt loam located on the Atlantic Coastal Plain near Plymouth, North Carolina. Most of the land was cleared of trees and brush for this study. None of the land used had a fertilizer history for at least twenty-five years. Through soil analysis and plant growth responses, the soil was shown to be deficient in phosphorus and calcium.

Soybeans both for hay and seed, and corn were planted to furnish a complete ration for the lambs. The soybean hay was grown in two adjacent eight-acre fields divided into a total of twelve plots. Six alternate plots received phosphate fertilization and the other six none. The corn and soybeans for the seed were planted in another field; each crop was arranged into six plots. Three of the plots received phosphate and three received no phosphate fertilization.

All plots received limestone at the rate of 500 pounds and potash equivalent to 80 pounds KCl per acre. All the phosphated plots received, in addition, the equivalent of 40 pounds of P_2O_5 per acre. The corn was also top-dressed with nitrogen. Each crop was planted into rows to permit weeding and cultivation.

Experimental Procedures, Results and Discussion

A preliminary study indicated that a ratio of non-phosphated to phosphated acreages of 2 to 1 would be required for equivalent yields. Accordingly, all plots receiving phosphate were one-half the size of the non-phosphated plots. The soybean hay yields for 1945 and 1946 were approximately one ton per acre for the phosphated plots and one-half ton per acre for the non-phosphated plots. Because of two abnormally wet seasons in 1945 and 1946, the corn crops for both years were a failure. Moreover, the soybean hay crop for 1945 was badly contaminated with *Paspalum Boscianum*, commonly referred to as bull grass, because the wet ground prevented proper cultivation.

Analysis of 1945 Crops

Samples of soybean hay and bull grass contaminate were taken from each of the twelve hay plots and analyzed. The results are shown in table 1. A statistical analysis of the data (Snedecor, 1946a) showed no significant difference in chemical composition of either species due to fertilization.

Feeding Trial, 1945

Thirty grade Hampshire wether lambs, averaging about 75 pounds in weight were purchased on a local market. The lambs were divided into six

TABLE 1. AVERAGE CHEMICAL COMPOSITION OF HAYS FROM PHOSPHATED AND NON-PHOSPHATED PLOTS[1] (AIR DRIED BASIS)

Constituents	Soybean hay			Bull grass hay		
	$+PO_4$[2]	$-PO_4$	Significance of $+PO_4$ effect	$+PO_4$	$-PO_4$	Significance of $+PO_4$ effect
Dry matter, %	94.51	94.51	N.S.	95.02	95.09	N.S.
Protein, %	20.74	19.94	N.S.	6.67	6.92	N.S.
Ether extract, %	6.30	5.98	N.S.	1.10	1.14	N.S.
Crude fiber, %	24.79	25.04	N.S.	32.49	32.44	N.S.
N.F.E., %	42.01	42.56	N.S.	51.93	52.59	N.S.
Ash, %	6.16	5.84	N.S.	7.80	7.57	N.S.
Phosphorus, %	.225	.191	N.S.	.115	.112	N.S.

[1] Each value is an average of six plots.
[2] $+PO_4$ = Phosphated plots; $-PO_4$ = Non-phosphate plots.
N.S. = Not significant ($P > .05$).

TABLE 2. SUMMARY OF LAMB FEEDING TRIAL, 1945 (70-DAY TRIAL).[1]
PART A. FEED INTAKE, GAINS, AND BOTANICAL COMPOSITION.
PART B. MEAN PERCENTAGE COMPOSITION OF RATION CONSUMED[2]

Part A

Items compared	Fertilization		Difference I–II
	I phosphate	II no phosphate	
Hay offered/lamb, lbs.	163.4	163.2	+ .2
Hay consumed/lamb, lbs.	145.4	146.7	−1.3
Raw soybeans/lamb, lbs.	70.4	70.4	0
Total gain/lamb, lbs.	11.13	12.77	−1.64 N.S.
Botanical composition, %[2]			
of hay offered, soybeans, %	58.8	51.3	−7.5*
of hay offered, bull grass, %	41.2	48.7	+7.5*
of hay consumed, soybeans, %	63.3	54.1	+9.18*
of hay consumed, bull grass, %	36.7	45.9	−9.18*

Part B: (dry matter basis)

Fertilization	Protein	Ether extract	Crude fiber	N.F.E.	Ash	Ca	P
	percent	*percent*	*percent*	*percent*	*percent*	*percent*	*percent*
Phosphate	24.78	9.15	21.99	36.66	7.43	.499	.271
No phosphate	24.04	8.48	23.73	36.68	7.07	.484	.253
$S\bar{x}$[3]	±.236	±.235	±.826	±.502	±.190	±.015	±.004

[1] Results are based on three pens of five lambs per pen on each treatment.
[2] Each figure is a mean of three samples.
[3] Standard deviation of a mean
N.S. = Not significant ($P > .05$)
* = Significant ($P \leq .05$)

groups of five lambs each. Three groups or pens were fed the feeds from the phosphated plots and three pens those from the non-phosphated plots. Each pen was restricted to the hay produced from two of the twelve field plots. In this manner each pen received hay raised from different parts of the fields. Due to the failure of the corn crop, soybeans (only) were fed as the concentrate at the rate of one pound per head per day. The data of the trial are summarized in table 2.

As shown in table 2, the hay from the unphosphated plots contained a greater proportion of bull grass. On the average, the lambs fed hay from the non-phosphated plots gained 1.64 pounds more per lamb than those fed

TABLE 3. VARIATION IN LAMB GAINS OBTAINED ON FEEDS GROWN ON DIFFERENTIALLY PHOSPHATED SOILS IN 1945 (70-DAY FEEDING TRIAL)

Pen No.	No. of animals	Fertilization	Av. daily gain/lamb, lbs.
1	5	Phosphated	.194
2	5	Phosphated	.174
4	5	Phosphated	.109
Average	15	Phosphated	.159
3	5	No phosphate	.260
5	5	No phosphate	.126
6	5	No phosphate	.160
Average	15	No phosphate	.182

hay from the phosphated plots, but the difference was not statistically significant. A study of table 3 shows that pen to pen variation was greater than between treatment variation. This emphasizes the importance of replication in experiments of this type.

Following the feeding trial, two lambs were selected at random from each pen, making a total of twelve lambs, for a digestion trial and determination of nitrogen balance. A 7-day preliminary period followed by a 10-day collection period was used in these trials. The lambs were continued on the same treatment during the digestion trial as on the feeding trial. Instead of compositing the hays from each plot within each treatment, however, a sample of hay from each plot was assigned to an individual lamb. The hay was fed uncut, and the ration approximated the feeding trial ration, i.e. hay plus 1 pound of soybeans per lamb per day. Careful botanical counts were taken on each hay sample and on the orts.

A statistical analysis of the data (Snedecor, 1946a) showed a significantly

greater digestibility in favor of the non-phosphate fertilized feeds for dry matter, crude fiber, and nitrogen-free extract (table 4). Furthermore, the six lambs on the non-phosphated feeds consumed on the average 223 gms. more bull grass and 132 gms. less soybean hay per lamb per day than the six lambs on the phosphate fertilized feeds. Because of these differences, a multiple covariance analysis was conducted on the data using bull grass and soybean hay consumed as the independent variables (Snedecor, 1946b). The adjusted treatment means were not significantly different. Thus, when the difference in bull grass and soybean hay was considered, no evidence was obtained to indicate that the fertilization affected digestibility. Apparently, the crude fiber and nitrogen-free extract of the bull grass plant was more highly digested than that of the coarse-stemmed soybean plant.

TABLE 4. SUMMARY OF DIGESTION TRIAL DATA,[1] 1945

Items compared	Fertilization		Difference I–II
	I phosphated	II, no phosphate	
Raw soybeans consumed/day/lamb, gms.	454	454	0
Total hay consumed/day/lamb, gms.	721	812	− 91.0
Soybean hay consumed/day/lamb, gms.	385	253	+132.0**
Bull grass hay consumed/day/lamb, gms.	336	559	−223.0**
Dry matter digestibility, %	62.6	65.5	− 2.9*
Crude fiber digestibility, %	51.7	59.7	− 8.0**
N.F.E. digestibility, %	52.4	58.4	− 6.0*

[1] Each figure is an average obtained with 6 lambs on each treatment. No significant difference found for digestibility of protein, ether extract, calcium and phosphorus, and in the nitrogen balance.

* = Significant ($P \leqq .05$)

** = High significant ($P \leqq .01$)

Results on 1946 Crops

Because some cultivation was possible, a much cleaner stand of soybean hay was obtained in the 1946 hay crop. The hays from the phosphated plots averaged 91.3% soybean hay and 8.7% bull grass hay, while the hays from the non-phosphated plots averaged 89.2% soybean hay and 10.8% bull grass hay. Statistical analysis of the data (Snedecor, 1946a) showed no significant differences in botanical composition between the hays from the two fertilizer treatments.

The lamb feeding trial on the 1946 crops was conducted with 30 lambs in much the same manner as in the 1945 feeding trial. However, because the average daily gains were below normal in the 1945 trial an attempt was made in the 1946 trial to improve growth by adding cerelose (corn sugar) to the

raw soybean concentrate. After 42 days of the trial, the combination of soybeans and cerelose was discontinued as a concentrate because the lambs went off feed frequently. For the next 63 days of the trial, the hay was supplemented with cerelose only and these troubles were avoided.

An analysis of variance of the gains made during the total period of 105 days indicated no significant difference in the hays from the two fertilizer treatments. The average daily gain per lamb was .198 pound for the phosphate treatment and .183 pound for the no phosphate treatment. However, for the 63-day period when the lambs received cerelose only as a supplement to the hay, a significant increase in total gain of 5.65 pounds per lamb was obtained for the lambs on hays from the phosphated plots. Besides the greater gains, the lambs on the phosphated hays during this period also utilized the feeds consumed more efficiently. The data for the 63-day period

TABLE 5. SUMMARY OF LAMB FEEDING TRIAL WITH SOYBEAN HAY AND CERELOSE[1] 1946. PART A. MEAN FEED INTAKE AND GAINS PER LAMB. PART B. MEAN PERCENTAGE COMPOSITION OF HAY CONSUMED

Part A

Items compared	Fertilization		
	I, phosphate	II, no phosphate	Difference I–II
Number of pens	3	3	0
Total number of lambs	15	14[2]	1
Hay offered/lamb, lbs.	167.6	167.9	.3
Total hay consumed/lamb, lbs.	108.0	110.3	−2.3
Soybwan hay consumed/lamb, lbs.	103.9	101.2	+2.7
Bull grass consumed/lamb, lbs.	4.1	9.1	−5.0
Cerelose consumed/lamb, lbs.	46.9	46.4	+ .5
Gain/lamb, lbs.	17.73	12.08	+5.65*[4]
Average daily gain/lamb, lbs.	.281	.192	+ .089*

Part B (dry matter basis)

Fertilization	Protein	Ether extract	Crude fiber	N.F.E.	Ash	Ca	P
	percent	*percent*	*percent*	*percent*	*percent*	*percent*	*percent*
Phosphate	24.98	9.68*	21.27	35.43	8.64	.92	.220
No phosphate	23.30	8.17	20.57	39.50	8.45	.88	.193
$S_{\bar{x}}$[3]	±.461	±.126	±.126	±.961	±.267	±.05	±.033

[1] Length of feeding period 63 days.

[2] One lamb died of pneumonia day before beginning of period.

[3] $S_{\bar{x}}$ = standard deviation of a mean.

[4] * = Significant ($P \leq .05$) when gains were adjusted for feed intake.

* = Significant ($\leq .05$)

are summarized in table 5. A critical interpretation of these results demands caution because it is difficult to separate the residual effects of the first 42 days of the trial on the subsequent 63-day period when cerelose alone was fed as the concentrate.

At the end of the feeding trial twelve lambs were selected at random from the six pens and an individual lamb was assigned to a sample of hay from

TABLE 5. SUMMARY OF LAMB DIGESTION TRIAL WITH SOYBEAN HAY AND CERELOSE, 1946. PART A. MEAN FEED INTAKE PER LAMB DAILY AND MEAN DIGESTION COEFFICIENTS OF INDICATED FEED CONSTITUENTS. PART B. MEAN PERCENTAGE COMPOSITION OF SOYBEAN HAYS

Part A

Items compared	Treatment[1]				Significance of treatment effect[2]	
	I $+PO_4$[3]	II $-PO_4$	III $+PO_4$ & C	IV $-PO_4$ & C	Phosphate	Cerelose
Daily hay intake/lamb, gms.	733.3	633.3	691.6	716.6		
Daily cerelose/lamb, gms.	0	0	203.6	239.0		
Dry matter, %	57.2	56.1	53.2	52.4	N.S.	**
Protein, %	74.6	71.3	69.3	67.7	*	**
Ether extract, %	81.3	80.3	79.7	77.8	N.S.	*
Crude fiber, %	43.5	41.1	38.5	39.0	N.S.	*
N.F.E., %	58.5	59.9	54.1	55.2	N.S.	**
Ash, %	42.7	41.1	41.8	35.7[*4]	N.S.[5]	N.S.
Phosphorus, %	7.7	6.1	14.3	3.3	N.S.	N.S.
Calcium, %	32.2	25.6	24.1	18.9	N.S.	*

Part B: (dry matter basis)

Treatment	Protein	Ether extract	Crude fiber	N.F.E.	Ash	Ca	P
	percent	*percent*	*percent*	*percent*	*percent*	*percent*	*percent*
Phosphate	19.85	6.13	28.87	35.51	9.65	.88	.165*
No phosphate	18.72	5.80	28.09	37.17	10.22	.76	.142
$S\bar{x}$[6]	±.441	±.145	±.416	±.417	±.421	±.040	±.044

[1] Each figure an average of six values.

[2] Phosphate fertilization effect = Treatments (I+III) vs. (II+IV)
Cerelose effect = Treatments (I+II) vs. (III+IV)

[3] $+PO_4$ = hays from phosphated plots; $-PO_4$ = hays from non-phosphate plots; C = cerelose.
N.S. = not significant ($P > .05$)
* = significant ($P \leq .05$)
** = highly significant ($P \leq .01$)

[4] ($P = .056$).

[5] Significant ($P \leq .05$) phosphate fertilization × cerelose interaction,

[6] $S\bar{x}$ = standard deviation of a mean.

each field plot in the same manner as in the digestion trial of 1945. However in the 1946 digestion trial the hays were chopped and the cerelose was fed at the constant ratio of three parts hay to one part cerelose. Moreover, digestibility was determined for hay alone and for hay plus cerelose. Whether a lamb received hay or hay plus cerelose in the first collection period was determined randomly. Each animal was fed from the same hay sample during both collection periods. Each collection period was preceded by a seven-day preliminary period. The mean digestibility of the feed constituents, the mean feed intakes and the mean percentage compositions of the hays are presented in table 6. The digestion coefficients for the total feed (hays plus cerelose) were calculated on the hays alone assuming that the cerelose was 100 percent digested.

Of particular interest (table 6) are (a) the significantly higher apparent digestibility of the protein in favor of the phosphate fertilization treatment and (b) the significantly lower digestibility of the ash in the non-phosphate fertilized ration consisting of hay plus cerelose. Moreover, the average protein content of the hays from the phosphated plots was 1.13 percent higher than the average for the hays from the non-phosphated plots. This small difference was not statistically significant due to the variation in protein content of the hays within the two fertilizer treatments.

Mitchell (1942) has shown that the apparent digestibility of protein it related to the level of protein fed. Consequently, it seemed desirable to test whether the difference in protein content of these two hays could account for the observed differences in apparent digestibility. Therefore, a covariance analysis was conducted on the data using percent protein in the dry matter as the independent variable (Snedecor, 1946c). The adjusted treatment means were not significantly different (table 7). Thus, no evidence was found that fertilization affected digestibility. Since the higher mean apparent digestibility of the protein in the phosphated hays was due to the quantity of protein present, there is no evidence that the quality of protein was different in the two types of hays.

TABLE 7. COMPARISON OF OBSERVED PROTEIN DIGESTIBILITIES WITH PROTEIN DIGESTIBILITIES ADJUSTED FOR PROTEIN CONTENT OF INDICATED RATIONS

Treatment	Protein, dry basis	Observed digestibility	Adjusted mean digestibility
	percent	*percent*	*percent*
Phosphated hays	19.85	74.6	71.3
Phosphated hays+cerelose	15.09	69.3	71.0
No phosphate hays	18.60	71.3	69.2
No phosphate hays+cerelose	14.05	67.7	70.4

TABLE 8. BLOOD SERUM PHOSPHORUS AT THE END OF THE 1946 DIGESTION TRIAL

Treatment	Mgs. of phosphorus per 100 ml. serum			
	Cerelose fed		No cerelose fed	
Phosphated hays	(2)[1]	7.08	(4)	7.43
No phosphate hays	(4)	5.85**	(2)	8.05

[1] Numbers in parenthesis =no. of lambs.

** Highly significant ($P \leq .01$) phosphate fertilization Xcerelose interaction.

The authors have no adequate explanation for the phosphate fertilization × cerelose interaction on the digestibility of the ash (table 6). It is interesting to note, however, (table 8) that a similar phosphate fertilization × cerelose interaction was found in the serum inorganic phosphorus content of the blood obtained from the experimental lambs after the last collection period.

These data show that the blood phosphorus level of the group of lambs on the ration consisting of non-phosphated hay plus cerelose was significantly lower than the other three groups. These same animals also had the highest excretion of ash in the feces. This suggests a relationship between blood phosphorus and fecal ash. Phosphorus was also determined in the feces and was found to be highest for the lambs on the ration of non-phosphated hay plus cerelose, the difference was not significant because of the great variation between lambs on the same treatment.

Discussion

Since work on this problem is being continued, the formulation of hypotheses will be left for a later date when more data are available. However, the data obtained in these experiments suggest some new methods of attack which, if pursued, should lead to basic information concerning the problem under study. The results of the animal studies reported indicate that replicating the animal feeding trials to correspond to the replications in the field assists both in estimating true differences and in evaluating the causative factors. For example, in the lamb digestion trial on the 1945 crops, significantly higher percentages of digestible crude fiber, digestible nitrogen-free extract and total bull grass were obtained for the non phosphate fertilized rations than for the phosphate fertilized rations (table 4). However, having both animals and field replications made it possible to adjust for the soybean and bull grass hay content of the respective hays. When this was done, no evidence was obtained that fertilization affected digestibility. This interpretation was substantiated by the digestion trial on the 1946 hay crop which provided a much cleaner stand of soybean hay.

Another example illustrating the value of keeping the field replication intact during the animal feeding trials was obtained on the 1946 hay crop. In this experiment (table 7) the higher apparent digestibility of the protein in the phosphated hays was shown to be associated in large measure with the quantity of protein rather than the quality of protein. When field replications are composited for animal studies, it is impossible to discern trends because the investigator has only a few values with which to work.

The data (table 5) also suggest that the use of a pure source of energy such as cerelose for the concentrate portion of the ration may accentuate potential differences in the nutritive value of forages resulting from fertilizer practices. It is recognized that cerelose is not used in practice but the results reported indicate it may be a useful technique for fundamental studies. Mineral studies reported both on the blood and on the fecal ash suggest the desirability of studying the metabolism of the minerals in more detail.

Summary

Phosphate fertilization of soybean hays grown on a Bladen silt loam soil deficient in phosphorus produced no significant change in composition as measured by standard feedingstuffs analysis, which included calcium and phosphorus. This was also true of the bull grass contaminant. Fattening trials and digestibility studies with lambs using soybean hay for roughage and raw soybeans for concentrate gave no significant differences either in weight gains or apparent digestibilities between feeds from phosphate-fertilized and those from non-phosphate-fertilized plots. When cerelose replaced soybeans as the concentrate, lambs which received soybean hay fertilized with phosphate gained an average of .282 pound daily per lamb as compared to .192 pound for the non-phosphate group. This difference was significant at the 5 percent level. Digestion studies using soybean hay alone as well as with cerelose as the concentrate on a second hay crop gave a significantly higher apparent digestibility for the protein of hay from the phosphate-fertilized plots. This was shown to be related to the quantity of protein rather than the quality of protein. Serum phosphate values and digestibility of ash by lambs fed hay from phosphate-fertilized plots plus cerelose were higher than those lambs receiving hay from non-phosphated plots plus sugar. Generalizations on the influence of fertilization on the nutritive value of plants for animal feed are not warranted at this stage of the investigation.

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THE CALCIUM, MAGNESIUM AND POTASSIUM CONTENTS OF THE SERUM OF EWES FED HIGH LEVELS OF POTASSIUM

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A FORM of tetany in livestock characterized by hypomagnesemia and sometimes hypocalcemia has been reported in many parts of the world. The literature on this subject has been reviewed by Russell (1944). The disturbance occurs most frequently in breeding cows and ewes that are grazed on young lush herbage. In the High Plains Region of the Southwestern United States it is a common practice to graze cattle and sheep on wheat pastures from late October to the middle of March. During seasons of good wheat growth these animals may develop symptoms characteristic of grass tetany as reported in other parts of the world and losses occur of sufficient magnitude to be of considerable economic importance. The malady is referred to by the stockmen in the Texas Panhandle area as "wheat poisoning." Studies carried on at this Station indicate that the condition is a typical grass tetany.

The most consistent biochemical lesions of cattle with grass tetany grazed on winter wheat are hypocalcemia and hypomagnesemia (unpublished data from the Texas Station). The serum calcium may drop from a normal of approximately 11.0 mg per 100 ml to less than 7.0 mg. per 100 ml. The decrease in the blood magnesium values is less consistent and pronounced than the decrease in the calcium values.

Grass tetany on wheat pastures does not appear to be due to an inadequate intake of calcium or magnesium. Analysis of a number of samples of the young wheat plant from areas where grass tetany occurred showed that the calcium content on the dry basis was between 0.30 and 0.40 percent. This is considerably higher than the level of calcium recommended by the National Research Council Committee (Guilbert *et al.*, 1945) for cows nursing calves. The dried wheat plant from the Texas Panhandle area contains in the order of 0.18 percent of magnesium. On the basis of studies with laboratory animals (Kunkel and Pearson, 1948) the magnesium in the wheat plant has a physiological availability of about 75 percent.

The young wheat plant gathered from farms on which grass tetany occurred was found to be very high in potassium containing in the order of 3.5 percent on a dry basis. This is 2 to 3 times more than is generally found in young herbage. The high potassium content of the wheat plant could

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conceivably be a factor in the etiology of grass tetany by interfering with the utilization or metabolism of calcium or magnesium.

The effect of the administration of large amounts of potassium nitrate has been studied by Seekles and Sjollema (1932). When potassium nitrate was administered as a drench, doses of 200 to 250 gm. were fatal to mature cattle. When the potassium nitrate was added to the ration and fed at intervals throughout the day the tolerance was of a much higher order than when it was administered as a drench. They fed amounts ranging from 750 to 900 gm. without observing any ill effects. The feeding of large amounts of potassium nitrate did not effect the level of calcium or magnesium in the serum.

Harbaugh and Dennis (1947) reported that cattle with grass tetany had a wide plasma potassium-calcium ratio. The plasma calcium levels of affected animals were very low, but the potassium levels were not consistently higher than for normal animals. It naturally follows that a hypocalcemia will result in a wide ratio between that element and any other constituent of the blood that remains constant. Later Dennis and Harbaugh (1948) reported that the oral administration of large amounts of potassium salts over a period of 5 or 6 days increased the potassium level of the serum, but did not significantly decrease the calcium content. The symptoms of tetany observed by these workers following the oral administration of large amounts of potassium may have been due to the resulting imbalance in the electrolytes of the circulating body fluids. Recent studies (Pearson, 1948) indicate that the feeding of high levels of potassium to rats receiving borderline levels of magnesium does not interfere with the utilization or metabolism of magnesium.

The present paper reports the effect of feeding high levels of potassium to breeding ewes on the amounts of potassium, calcium and magnesium in the serum.

Experimental

Six mature ewes were selected for these studies. They were fed a liberal allowance of alfalfa hay and a limited amount of ground grain. Potassium bicarbonate was mixed with the grain in amounts calculated to provide an intake of potassium equivalent to 5 percent of the ration. It required a few days for the sheep to become accustomed to the grain-potassium bicarbonate mixture. After the first week the animals readily consumed the mixture. Since the ewes had free access to the alfalfa the potassium intake was not exactly equivalent to 5 percent of the ration.

Blood samples were drawn from the jugular vein at monthly intervals. The serum from each animal was analyzed for calcium, magnesium and potassium. Calcium was determined by the method of Kramer and Tisdall

(1921) as modified by Clark and Collip (1925); magnesium by the method described by Kunkel, Pearson and Schweigert (1947) and potassium by the method of Van Slyke and Rieben (1944). Towards the end of the experiment and after the ewes had been receiving the potassium diet for between 4 and 5 months blood was obtained from 12 ewes that had been fed a standard ration with access to pasturage. The blood values of these animals may be considered normal and are shown in table 1 for comparative purposes. During the course of the feeding period the ewes receiving the potassium diet gained weight.

The data in table 1 for the ewes receiving the potassium diet show the average for the 6 ewes for each month. The variation among the animals for each constituent studied was relatively small. The maximum calcium

TABLE 1. THE EFFECT OF FEEDING POTASSIUM ON THE CALCIUM, MAGNESIUM AND POTASSIUM CONTENTS OF THE SERUM

Month on ration containing 5% K	Calcium	Magnesium	Potassium	Ratio	
				K/Ca	K/Mg
	mg./100 ml.	*mg./100 ml.*	*mg./100 ml.*		
1*	11.6	2.1	19.1	1.6	9.1
2	12.1	2.2	17.8	1.5	8.1
3	12.1	1.9	18.3	1.5	9.6
4	11.5	1.9	20.3	1.8	10.7
Average for 12 ewes on stock ration	10.6	2.3	18.2	1.7	7.9

* First blood samples taken after ewes had been on experimental rations for one month. Values represent the average for six ewes except for K for periods 3 and 4 when the average is for four and five ewes for the respective periods.

level of 12.1 mg. per 100 ml. of serum cannot be considered significantly different from the value of 10.6 mg. per 100 ml. for the ewes on the stock ration.

The magnesium content of the serum was remarkably constant ranging from 1.9 to 2.2 mg. per 100 ml. as compared with 2.3 mg. for the ewes on the stock diet. The potassium levels of the serum are very interesting in that adding 5 percent of potassium to the diet did not increase the level in the blood. The average serum potassium content for the ewes on the standard ration was 18.2 mg. per 100 ml. while the average values for the ewes receiving the potassium diet ranged from 17.8 to 20.3 mg.

From these data it is apparent that the addition of 5 percent of potassium to the ration of breeding ewes did not significantly influence the levels of calcium, magnesium or potassium in the serum of the sheep. The potassium must have been eliminated very rapidly by the renal pathway.

Dennis and Harbaugh (1948) observed an increase in the potassium level of the serum of two cows fed potassium chloride and potassium citrate.

While the amount of feed consumed by their animals is not given, it can be estimated that the intake of potassium in their experiments with cows was no higher per unit of body weight than for the ewes in our experiments. Possibly different potassium salts differ in their rates of absorption and/or excretion or there may be a species difference in the response of the cow and sheep following the feeding of potassium.

That there is a physiological interrelationship between potassium and sodium has been shown by recent work of Conway and Hingerty (1948). These workers found that high plasma potassium values are accompanied by a decrement in the sodium in the muscle. This observation suggests that the symptoms observed by Dennis and Harbaugh (1948) following the administration of large amounts of potassium might be due to an imbalance in the cations of both sodium and potassium.

One of the ewes gave birth to a lamb soon after the beginning of the experiment. After several weeks the lamb died from some unidentified cause. To determine if the high potassium intake of the mother could have been connected with the death of the lamb a sample of the ewe's milk was collected. The milk contained 111.7 mg. of potassium per 100 ml. as compared with 112.5 mg. per ml. of milk from a ewe on a stock ration.

Summary

The ingestion by mature ewes of a ration containing approximately 5 percent of potassium as the bicarbonate did not have a significant effect on the amounts of calcium, magnesium or potassium in the blood serum.

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VITAMINS A AND C CONCENTRATIONS IN THE BLOOD PLASMA OF EWES, THEIR MILK, AND IN THE BLOOD PLASMA OF THEIR LAMBS[1]

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WHILE it is assumed that vitamin deficiencies among sheep are not as common as with other classes of livestock more closely confined, lambs have high infant mortality. There are too few accurate production records available to gauge the exact number of these death losses, but one such record is reported by Bell (1944). His records, covering a 10-year period, reveal that 23 percent of the Shropshire lambs in the Station flock failed to reach two months of age. The causes of these lamb deaths were classified into 12 categories, some of which may be directly or indirectly traced to nutrition. For example, two of the death causes were scours and pneumonia.

Losses from similar causes are prominent in dairy cattle. The relationship between scours and pneumonia in calves and deficiencies in certain vitamins, was observed by Phillips (1941). Since some of the infant mortality in lambs may be due to a parallel situation, this work was organized to investigate that possibility. However, since very little work has been done to establish normal vitamin blood levels in ewes and growing lambs, the work reported in this paper deals with that phase of the study.

Experimental

Eighteen grade Hampshire-Shropshire ewes were used in this experiment and involved two lambing seasons. During the second year eight of the original ewes were replaced. There was no significant difference between the analyses on the same ewes or their lambs over the two-year period.

While these experimental sheep were maintained in dry lot during the experiment, they were managed about like the average Wisconsin farm flock. The ewes were on pasture during the pasture season. They were fed a good quality alfalfa-brome grass hay plus a grain mixture of corn, oats, bran, and linseed meal a few weeks prior to lambing and during lactation. The lambs were born in early March, and when old enough to eat grain were given access to a creep containing the same grain mixture as the ewes.

The ewes were bled several weeks before parturition and after lambing. The lambs were bled immediately after birth and before they had nursed. They were bled again at 18–30 hours of age, at 4 days of age, and once a week thereafter at the same time as their dams.

[1] Published with the approval of the Director of the Wisconsin Agricultural Experiment Station, Madison, Wisconsin.

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Fifteen milliliters of blood were drawn for each sample from the jugular vein. The blood was placed immediately in an ice thermos jug and analyzed within a few hours. Both vitamins A and C could be run on the same sample with this quantity of blood. The vitamin A was determined according to the method of Kimble (1939) and the vitamin C by the Mindlin and Butler method (1938).

Carotene analyses were made on all samples during the first year's work. However, the maximum amount present even when the sheep were on pasture was 0.09 gamma per cc. of plasma. In many cases there was none. Since the colorimetric procedure used was not sufficiently sensitive, this minute amount could have been due to experimental error and no carotene values are reported. It may be concluded as other investigators have observed that sheep are very efficient converters of carotene to vitamin A.

In an attempt to explain certain variations found in the lamb's blood plasma at different stages of growth, colostral and normal milk were analyzed for vitamins A and C. All vitamin C determinations were made according to the method outlined by Woessner (1939). This entailed the use of a modified Willberg reagent for precipitating the protein and for insuring the proper pH in the colorimeter tube. Since it required 30 cc. of milk to run both vitamins A and C analyses, it was necessary to remove the lambs from their dams for a period of several hours so that enough milk could be obtained. Usually this was necessary only after the first week since before that time the ewes had more than the lambs could consume. Upon collecting the samples both sides of the udder were milked completely dry.

The method described by Boyer *et al.* (1944) was used for the vitamin A determinations. No carotene was found in either the colostral or later milk.

Results and Discussion

Table 1 shows the vitamin A values obtained for the ewes during the last part of pregnancy and through lactation. There was no significant drop in blood plasma vitamin A immediately before or following parturition. As a check several ewes were bled within 12 hours of lambing and immediately after parturition. There was no significant difference between the analyses.

This is in contrast with the results reported by Sutton and Soldner (1943) with dairy cows. They observed a drop of approximately 50 percent in both the blood plasma vitamin A and carotene three days prior to and three days after parturition. The highest blood plasma vitamin A concentration of these ewes occurred during the first eight weeks of lactation. This confirms the results found by Weir *et al.* (1946).

With respect to the lambs' blood plasma A level, it was low at birth as shown in table 2. This was only one-sixth to one-seventh the amount

TABLE 1. VITAMIN A CONTENT IN THE BLOOD PLASMA OF EWES, γ/100 cc.

Items compared	Before parturition			After parturition													
	1 mo. before	12 hr.–3 days	Parturition	18–30 hr.	4 da.	1 wk.	2 wk.	3 wk.	4 wk.	5 wk.	6 wk.	7 wk.	8 wk.	9 wk.	10 wk.	11 wk.	12 wk.	13 wk.
No. of cases	36	21	36	34	34	37	29	26	25	8	10	10	8	4	8	7	5	3
Range:																		
Low	27	25	22	17	30	26	25	31	33	33	25	31	34	34	31	31	34	38
High	50	53	52	52	60	62	63	72	69	47	50	70	56	39	49	45	47	65
Mean	39	41	37	37	43	44	42	44	45	42	41	41	43	37	39	39	40	48

TABLE 2. VITAMIN A CONTENT IN THE BLOOD PLASMA OF LAMBS, γ/100 cc.

Items compared	Birth	18–30 hr.	4 da.	1 wk.	2 wk.	3 wk.	4 wk.	5 wk.	6 wk.	7 wk.	8 wk.	9 wk.	10 wk.	11 wk.	12 wk.	13 wk.
No. of cases	42	45	46	44	38	31	29	10	13	14	10	6	8	8	8	5
Range:																
Low	2	7	10	9	12	15	15	16	14	16	20	18	18	19	15	18
High	22	49	43	46	42	41	35	33	38	39	30	33	36	41	38	28
Mean	6	20	20	23	23	24	24	25	27	26	24	26	26	33	24	26

found in their dams. After the lambs received colostrum there was a sharp rise to 20 gamma at the second bleeding. However, the lambs' blood plasma vitamin A remained in a rather narrow mean range of 20 to 33 gamma during their first 13 weeks of life. This was considerably below the ewes' level as shown by figure 1.

The vitamin C blood level of the ewes shown in table 3 was similar to their vitamin A picture. The lowest values occurred the first few days after parturition and then increased above the values during pregnancy. This

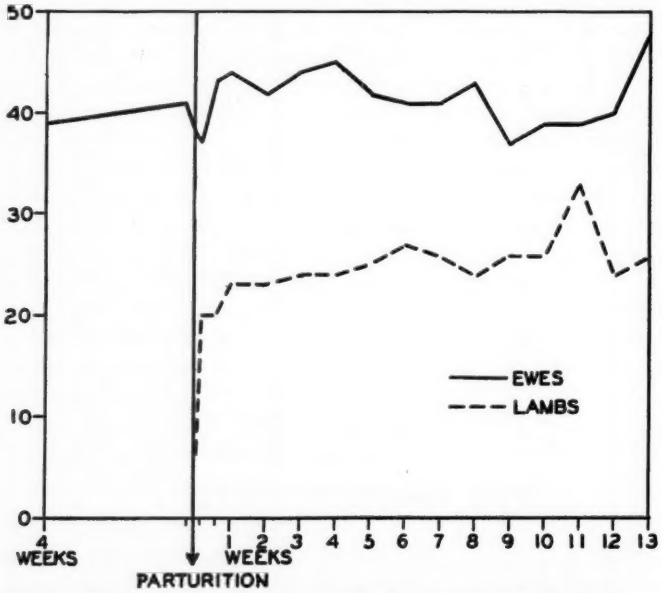

Figure 1. Blood plasma vitamin A concentration of ewes and their lambs.

again confirms Weir's analyses which showed a ewe's vitamin C blood level to be highest during lactation.

The vitamin C blood plasma level of .30 mg. for these lambs at birth as seen in table 4 was also low when compared to the ewes' values of .58 to .99 mg. per 100 cc. plasma. The ingestion of colostrum did not cause a sharp increase as in the case of vitamin A. On the contrary, there was a slight decrease through the fourth day. However, by the end of one week it was approaching the level of their dams and after two weeks of age, these values were in the normal range of .44 to .70 mg. per 100 cc. plasma. This was much

TABLE 3. VITAMIN C CONTENT IN THE BLOOD PLASMA OF EWES, mg./100 cc.

Items compared	Before parturition		Parturition	After parturition														
	App. 1 mo. before	12 hr. –3 da. before		18–30 hr.	4 da.	1 wk.	2 wk.	3 wk.	4 wk.	5 wk.	6 wk.	7 wk.	8 wk.	9 wk.	10 wk.	11 wk.	12 wk.	13 wk.
No. of cases	36	21	32	32	32	32	34	27	25	11	12	14	13	7	9	7	6	3
Range:																		
Low	.63	.50	.58	.39	.38	.44	.31	.44	.45	.63	.39	.41	.56	.57	.64	.64	.59	.57
High	1.06	.95	.99	.81	.99	.95	1.18	1.36	1.21	1.23	.98	1.58	1.10	.89	1.06	.93	.99	.97
Mean	.76	.73	.75	.62	.58	.63	.71	.76	.78	.85	.76	.78	.83	.77	.81	.78	.76	.70

TABLE 4. VITAMIN C CONTENT IN THE BLOOD PLASMA OF LAMBS, mg./100 cc.

Items compared	Birth	18–30 hr.	4 da.	1 wk.	2 wk.	3 wk.	4 wk.	5 wk.	6 wk.	7 wk.	8 wk.	9 wk.	10 wk.	11 wk.	12 wk	13 wk.
No. of cases	40	40	40	46	43	33	30	13	16	20	17	8	12	7	9	5
Range:																
Low	.11	.12	.11	.21	.27	.18	.23	.23	.22	.42	.38	.34	.35	.40	.39	.52
High	.94	.82	.48	.70	1.09	.93	.75	.65	.79	1.03	.89	.92	.86	1.03	.94	1.26
Mean	.30	.27	.23	.40	.58	.56	.47	.44	.54	.66	.61	.63	.60	.66	.64	.70

nearer the level of their dams, as seen by figure 2, than was true in the case of vitamin A.

The vitamin A content of the ewes' milk, as shown in table 5, was very high in the colostral milk. There was a gradual decrease until a rather constant value was reached by the seventh day. Farther along in lactation there was a gradual increase.

It is evident from table 6 that the colostrum analyzed was not significantly

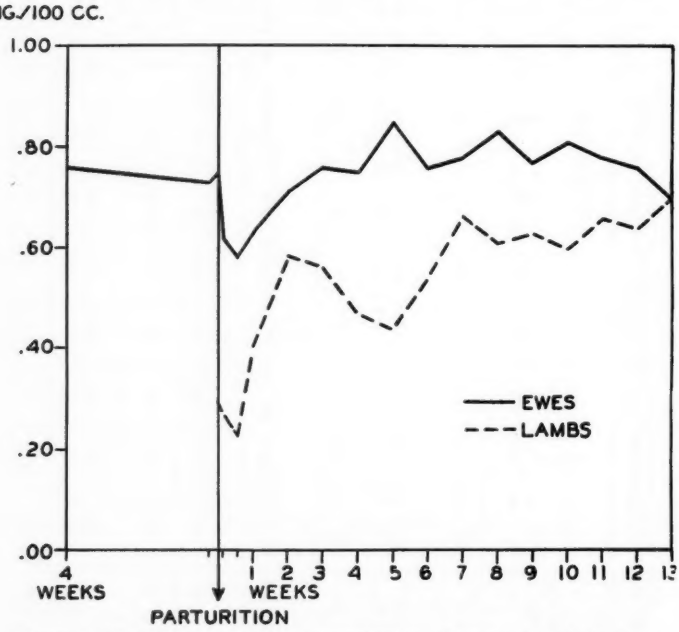

Figure 2. Blood plasma vitamin C concentration of ewes and their lambs.

higher in vitamin C than the normal milk. While these colostrum values compare favorably with those reported by Satterfield (1942) where he found ewes' colostrum to contain from 2.01 to 9.94 mg. per 100 cc., the normal milk C values are much higher. He reports normal milk containing only 0.43 to 0.82 mg. percent. There appeared to be no increase in milk vitamin C as lactation progressed, therefore differing from the milk of cows reported by Rasmussen (1936). These values, however, are consistently higher than those of 1.9 to 2.1 mg./100 cc. for cows' milk also reported by Rasmussen (1938).

TABLE 5. VITAMIN A CONTENT OF EWES' MILK, γ/100 cc. MILK

Items compared	Stage of lactation								
	Colostrum	1 da.	4 da.	7 da.	14 da.	40–60 da.	61–80 da.	81–100 da.	101–125 da.
No. of cases	8	6	4	2	2	6	6	8	9
Range:									
Low	101	128	45	14	23	23	16	32	40
High	270	237	75	48	38	48	56	59	83
Mean	214	193	61	31	31	32	34	46	60

TABLE 6. VITAMIN C CONTENT OF EWES' MILK, mg./100 cc. MILK

Items compared	Stage of lactation											
	Colostrum	1 da.	4 da.	7 da.	14 da.	21 da.	22–40 da.	41–50 da.	51–60 da.	61–80 da.	81–100 da.	101–125 da.
No. of cases	7	7	7	6	7	6	6	5	5	6	10	9
Range:												
Low	1.03	2.40	3.00	2.98	3.07	3.72	3.60	3.10	3.42	2.98	2.56	2.42
High	5.70	5.04	4.10	4.15	4.45	4.87	4.80	4.58	4.47	4.49	4.45	4.54
Mean	3.98	3.97	3.86	3.71	4.10	4.22	4.36	3.90	4.16	4.06	3.73	3.33

Discussion

These lambs were deficient at birth in both blood plasma vitamins A and C when compared to their dams. The vitamin A concentration increased approximately threefold after the lambs received colostrum. This is not as large an increase after colostrum ingestion as reported by Peirce (1947) who found a sixfold increase. However, his sheep were grazed throughout the year. The range of 20 to 33 gamma after the 18–30 hour bleeding was considerably below their dams which ranged between 37 and 48 gamma. Unpublished work at this Station indicates that lambs up to approximately a year of age fall within this lower range and do not have as high a concentration as mature sheep regardless of feed or pasture. It may be concluded that there is a normal maximum limit during the first few months of life above which the lambs do not go, and during which time they are slowly accumulating liver stores of vitamin A. This may be of practical importance in possible vitamin A deficiencies of young growing lambs as compared to mature sheep.

There was a small variation in the vitamin A blood values of the ewes through the last month of parturition and during lactation. Even though the lowest values occurred the day following parturition, the decrease was in-

significant. On the contrary there is a marked drop in plasma vitamin A in the dairy cow at this time. The comparison would indicate that either the demands on the ewe are not as great at parturition as for the cow, or that liver storage is considerably greater in sheep.

Although colostrum quickly alleviated the low plasma vitamin A level of newborn lambs because it was a rich source of this vitamin, the inverse was true with respect to vitamin C. Despite the fact that these lambs were comparatively low in plasma vitamin C at birth, they were even lower at four days of age. The colostrum analyzed was not higher in vitamin C than normal milk. While the vitamin C blood level of the lambs approached that of their dams at a much earlier age than did the vitamin A, it may be concluded that the lambs were certainly low in vitamin C during their first four days of life and that colostrum did not supply enough to cause an increase.

Although the colostrum was a rich source of vitamin A, it is interesting to divide the first and second day milkings of the ewes that produced singles and twins. Of the six cases the average vitamin A of the colostrum from the ewes with singles was 224 gamma per 100 cc. From the ewes with twins the average content of the colostrum was 255 gamma. However, on the second day milking the milk of ewes with singles contained 189 gamma as compared with 131 gamma for the ewes suckling twins. This was a drop of 124 gamma for the ewes with twins and a decrease of 35 gamma for the ewes with singles. This did not prove significant in the blood plasma of their respective lambs, but suggests that the rate of transfer from colostral to normal milk depends to some extent on the number of young.

According to the values for cattle reported by Sutton (1943) and the values for calves reported by Lundquist (1943) a comparison of the plasma vitamin A level of cattle and sheep showed the sheep to be considerably higher. Where sheep contain no traceable amounts of carotene, however, cattle contain more carotene than vitamin A. Sutton states the plasma vitamin A level average of several breeds to be 16 gamma per 100 cc. plasma. While the ewes in this experiment averaged from two to three times that amount, these cattle also contained approximately 400 gamma of carotene per 100 cc. plasma. Lundquist reports calves to average from 14 to 17 gamma of vitamin A from one day to six weeks of age. The lambs in this experiment ranged from 20 to 30 gamma during this stage, but the calves also contained from 14 to 36 gamma of carotene. Thus a comparison of the vitamin A status in the two species is difficult.

Wallis (1943) reports the vitamin C blood plasma level of cows receiving pasture or winter feed to range from 0.27 to 0.43 mg. per 100 cc. of plasma. This would be roughly one-half the amount of ascorbic acid found in these

experimental sheep. Lundquist reports that 45 calves averaged 0.70 mg. percent of vitamin C at birth, which is considerably more than the average of these lambs. However, with calves he found a steady decline until two weeks of age when they averaged 0.19 mg. This was followed by an increase and a stabilization at approximately 0.30 mg. about three or four weeks of age. Thus the blood plasma vitamin C level of sheep appears to be considerably higher than that of cattle.

These vitamins A and C blood values for sheep appear to be much higher in most cases than for swine reported by Grummer (1948). However, he found an increase of vitamin C in the blood of newborn pigs rather than a decrease during the first 36 hours of life.

Summary

Blood analyses of lambs showed that they were deficient at birth in blood plasma vitamins A and C compared with their dams.

The plasma vitamin A levels of these lambs reached an apparently normal range of 20 to 33 gamma per 100 cc. plasma following the ingestion of colostrum. However, at no time during the experiment did the lambs' plasma vitamin A levels reach those of the ewes.

The colostrum analyzed contained approximately six to seven times as much vitamin A as the later milkings. An inverse condition was found in regard to the vitamin C picture of the young lambs. While they were born comparatively low in plasma vitamin C, these values decreased through the first four days of life before rapidly increasing to a normal level.

The fact that the colostrum analyzed was no higher in vitamin C than the normal milk, perhaps accounts for this decrease in the plasma of the lambs. At any rate, these lambs were low in vitamin C during their first four days of life and colostrum did not sustain the blood plasma ascorbic acid concentration within the normal range of older sheep.

The ewes' plasma vitamins A and C values were consistently higher during lactation than at any other period.

No measurable amount of carotene was found in the plasma or milk of these ewes. Hence it is concluded that sheep are efficient converters of carotene to vitamin A. A comparison of plasma vitamins A and C levels of sheep and other species is discussed.

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TAILLESS SPERM FROM RAMS

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THE percent of abnormal sperm in a semen sample has been considered as one index of fertility. A more accurate interpretation of abnormal types would improve the value of this index. Mercier and Salisbury (1947) demonstrated that the proportion of tailless sperm in smears of bulls' semen was increased by clearing the slides in chlorazene, or decreased by storing the semen for 4 days before making smears. Emik and Sidwell (1947) found the opal blue method to be superior to techniques of smearing followed by staining, principally because it produced fewer abnormal sperm, permitted an estimation of live sperm, and made a stained slide immediately available for examination.

Data compiled during the latter investigation were adaptable to tracing some of the relationships between proportions of tailless sperm and techniques. These relationships were combined with other observations to obtain a means of estimating the proportions of tailless sperm produced in vivo or created in vitro.

Materials and Methods

Most of the data for this report were collected at the same time and from the same rams under the conditions described by Emik and Sidwell (1947). Counts of tailless sperm were made by two workers from three sources: (1) with a hemacytometer from 1:200 dilutions of semen in phosphate buffered solutions of opal blue and eosin, with minute quantities of chlorazene, formalin, or phenol added to some preparations to inhibit motility; (2) from 1:200 dilutions of the same ejaculates in 4 percent chlorazene; and (3) for each sample from opal blue stained smears.

Percentages of tailless sperm were determined from counts of 100 sperm. These percentages, for each individual count, were transformed for use in analysis according to the method proposed by Bartlett (1947) for normalizing their distribution. The table originated by C. I. Bliss and published in Snedecor (1946) was used to transform percentages to angles in degrees.

The transformed means of the data from dilutions with phosphate buffered solutions of opal blue and eosin, or dilutions with chlorazene, ($\bar{X}$'s), were compared with the transformed means from the opal blue smears, ($\bar{Y}$), by the complete t formula:

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$$t = \frac{\bar{x} - \bar{Y}}{\sqrt{\sigma_x^2 + \sigma_y^2 - 2r\sigma_x\sigma_y}}.$$

Analyses of covariance were also made following the methods given in Snedecor (1946).

Results and Discussion

The comparisons of means of the transformed data are given in table 1. The percentages of tailless sperm from the opal blue smears were signifi-

TABLE 1. PERCENT TAILLESS SPERM IN PHOSPHATE BUFFERED OR CHLORAZENE DILUTIONS IN THE HEMACYTOMETER (X) COMPARED WITH OPAL BLUE STAINED SMEARS (Y), PERCENT TRANSFORMED TO ANGLES

Semen quality	Preparation	Ram no.	Transformed varieties						Actual percents	
			n	$\bar{X}$	$\bar{Y}$	σ_D	t	r	$\bar{x}$	$\bar{y}$
Good	Phosphate	142RW	15	8.59	8.51	2.14	1	.20	2.23	2.19
		2260W	8	9.90	8.49	0.96	1.47	.64	2.95	2.18
		Sum	23	9.05	8.50	1.33	1	.07	2.48	2.18
	Chlorazene	142RW	13	9.22	9.72	1.24	1	.08	2.57	2.85
		2260W	7	6.90	9.19	1.47	1.57	.68	1.45	2.55
		Sum	20	8.41	9.54	0.93	1.21	.38	2.14	2.75
Total good			43	8.75	8.98	0.82	1	.19	2.32	2.44
Poor	Phosphate	88RW	12	45.93	51.39	2.26	2.42*	.90**	51.6	61.1
		384RW	15	46.09	53.22	1.29	5.53**	.68**	51.9	64.1
		Sum	27	46.02	52.41	1.25	5.10**	.87**	51.8	62.8
	Chlorazene	88RW	11	46.94	51.35	2.32	2.32*	88**	53.4	61.0
		384RW	12	49.08	54.04	1.19	4.18**	.75**	57.1	65.5
		Sum	23	48.05	52.75	1.25	3.75**	.86**	55.3	63.4
Total poor			50	46.96	52.57	0.86	6.48**	.86**	53.4	63.1

* probability less than .05.
** probability less than .01.

cantly higher than those from either dilution, for the rams with semen of poor quality. There were no significant differences between means for the rams with semen of good quality. The correlations between percent tailless sperm from dilutions and from smears were uniformly highly significant for poor rams and non-significant for the good rams.

Differences between workers, dilution preparations, rams and rams grouped by semen quality were tested by covariance methods as presented

in table 2. There were no differences between workers or preparations for means or for regression coefficients. There were highly significant differences between semen quality groups for both means and regression coefficients. Rams within semen quality groups were not significantly different for either statistic. Analyses within semen quality groups indicated that no important effects were masked by pooling the dissimilar groups. When large percentages of tailless sperm were found in the diluted semen, significantly greater percentages of tailless sperm were present in the corresponding opal blue stained smears. This increase was due to two components, one

TABLE 2. TESTS OF SIGNIFICANCE OF MEANS AND REGRESSION COEFFICIENTS FOR COVARIANCE RELATION OF HEMACYTOMETER DILUTIONS TO OPAL BLUE STAINED SMEARS

Source	For means			For regression coefficients		
	Degrees of freedom	Error of estimate	Mean square	Degrees of freedom	Error of estimate	Mean square
Within workers	90	4183.1452	46.4793	89	4300.2736	45.2839
Between workers	1	0.0808	0.0808	1	152.8716	152.8716
Within preparations	90	4182.3360	46.4704	89	4166.0296	46.8093
Between preparations	1	0.8900	0.8900	1	16.3064	16.3064
Within semen quality	90	3098.8493	34.4316	89	2597.6051	29.1865
Between semen quality	1	1084.3767	1084.3767**	1	501.2442	501.2442**
Within rams & semen quality	88	3071.6445	34.9050	87	2465.3309	28.3371
Between rams & semen quality	2	27.2048	13.6024	2	132.2742	66.1371

** Probability less than .01.

represented by the regression 1.049, which was not significantly different from 1.000, and the other the intercept value of 3.314. The intercept value would make an increase of nearly 6 percent at an observed value of 50 percent for the dilution, on the original scale. Biologically speaking, these statistics indicate that smearing placed a constantly greater strain upon the necks of the sperm than did dilution, thereby causing more to break and form tailless sperm, in semen samples of poor quality. Since smearing created no more tailless sperm than diluting when good samples were used, a weakness of some nature made the necks of sperm in the poor samples susceptible to breakage.

The numbers of tailless sperm were not significantly different between dilutions made with phosphate buffer and dilutions made with chlorazene. The increased numbers of tailless sperm noted by Mercier and Salisbury (1947) were probably due to the physical effects of the process of clearing and staining, rather than to any specific effect of chlorazene upon the necks of the sperm.

It was found, from observation of a drop of semen and a drop of opal blue stain gradually mixing under a cover slip, that sperm which were motile never exhibited any stain in the head and when their motility was lost they invariably stained with both opal blue and eosin. The opal blue stained the post-nuclear cap region and eosin stained the head throughout. Eosin entered first, at the base of the head, and gradually spread to the tip. When poor semen was observed, large proportions of tailless heads were seen which nearly all stained only with eosin. Ten slides each of good and poor semen were reexamined (table 3) and the sperm classified according to whether the heads stained only with eosin or took both stains or neither. The mean number of tailless sperm taking no stain or both stains was not significantly

TABLE 3. STAINING REACTIONS OF SPERM DIFFERENTIATED BY THE USE OF OPAL BLUE AND EOSIN WITH VARIATES TRANSFORMED

Sample number	Good quality semen				Poor quality semen			
	Normal sperm taking—		Tailless sperm taking—		Normal sperm taking—		Tailless sperm taking—	
	No stain or both	Eosin stain only	No stain or both	Eosin stain only	No stain or both	Eosin stain only	No stain or both	Eosin stain only
1	69.73	0	18.44	8.13	33.83	9.98	19.37	47.87
2	80.02	0	9.98	0	42.71	12.92	8.13	43.28
3	84.26	0	0	5.74	9.98	8.13	5.74	75.82
4	67.21	0	9.98	20.27	11.54	11.54	0	73.75
5	75.82	0	11.54	8.13	49.02	8.13	5.74	39.23
6	84.26	0	5.74	0	48.45	5.74	12.92	38.06
7	90.00	0	0	0	43.85	12.92	5.74	42.71
8	74.66	0	12.92	8.13	46.15	8.13	0	42.71
9	75.82	0	14.18	0	35.06	5.74	9.98	52.53
10	81.87	0	5.74	5.74	32.59	0	0	57.42
Mean	78.36	0	8.85	5.61	35.32	8.32	6.76	51.32
Actual %	95.9	0	2.4	0.96	33.4	2.1	1.4	60.9

different between good and poor semen. None of the normal sperm from good semen took only eosin.

Opal blue stained smears were made of semen from the ampulla, tail of the epididymis and head of the epididymis upon autopsy of 384RW and five additional rams not contributing to the previous data. Three rams with good quality semen exhibited practically no tailless sperm at any location. The smears from 384RW and two other rams with defective semen of the same type were very similar in pattern. There was no difference between the head and tail of the epididymis, the tailless sperm constituting less than 10 percent and live and normal sperm being greater than 90 percent. In the ampulla the tailless sperm had increased to 20 percent with a corre-

sponding decrease in live and normal sperm. The final ejaculates contained 60 to 90 percent tailless sperm, and low percentages of live and normal sperm. From counts of 100 tailless sperm, the percent of heads taking both stains or no stain averaged 87 for the epididymis, 8 for the ampulla, and 3 for the ejaculates.

Evidently the sperm generally became tailless after leaving the epididymis. Further experimentation would be necessary to determine whether the unstained tailless sperm in the epididymis were entirely created by the smearing technique, or whether a portion of them were truly tailless. However, the point is not important since the greater proportion of the tailless sperm in ejaculates must have been derived from sperm which appeared live and normal in the epididymis. The results indicate that tailless sperm staining only with eosin should be classified as abnormal. Tailless sperm which take no stain or both eosin and opal blue are probably normal sperm that have been injured in the staining technique.

Summary

The differential features of tailless sperm from a pair of rams with good semen qualities and a pair with poor semen qualities were examined. Counts were made from dilutions in the hemocytometer, using chlorazene and phosphate buffer as the two diluents, and from opal blue stained smears. Differences between means of transformed percentages and analysis of covariance were utilized.

Smearing created no more tailless sperm than diluting if good quality semen was used but if poor quality semen was used about 6 percent additional tailless sperm were produced by smearing when 50 percent were found in the dilution. The percentage of tailless sperm, as measured in the hemocytometer, was practically the same whether chlorazene or phosphate buffer was used as the diluent. Differences between workers, dilution preparations and rams within semen quality groups were not significant by covariance analysis. Differences were highly significant between the pairs of good and poor rams.

In opal blue stained smears of good quality semen, heads of morphologically normal sperm took no stain or both eosin and opal blue, while the tailless sperm were about equally divided between this type and those staining only with eosin. In smears of poor semen, most of the tailless sperm and a small percent of morphologically normal sperm took only eosin. The percentage of tailless sperm which took no stain or stained with both stains was not different between the two qualities of semen.

Stained smears of semen from the epididymis, ampulla and final ejaculates of autopsied rams were examined. No changes in percent tailless sperm

were revealed for three good rams, whereas for three rams with comparably poor semen percentages in the epididymis were similar to the good semen but a definite increase of tailless sperm was shown in the ampulla with the most marked increase occurring between the ampulla and ejaculates. Tailless sperm staining only with eosin, as a percent of all tailless sperm, increased in a corresponding progression from epididymis to ejaculate.

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THE EFFECTS OF ENVIRONMENTAL AND HEREDITARY FACTORS ON TRICHOSTRONGYLID WORM INFESTATION IN SHEEP

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SUCCESSFUL estimates of the heritability of many quantitative characters depend upon the proper evaluation of, and adjustment for, environmental effects which mask or influence the phenotype. The interactions of heredity and environment have consequently been receiving increasingly careful attention by research workers in animal breeding. The application of proper statistical techniques has also improved the value of more recent data. The object of this study was to evaluate various environmental and statistical factors which may influence the level of counts of parasites' eggs, and to estimate the heritability of the resistance.

Stewart, Miller and Douglas (1937), Gregory (1937), Stewart and Douglas (1938), and Emik (1947) have demonstrated differences in level of trichostrongylid infestation (as measured by counts of parasites' eggs from fecal samples) between individuals and breeds of sheep which may be partially ascribed to genetic differences in resistance. Gregory, Miller and Stewart (1940), using Hampshire ewes, found differences between 1.7 and 2.7 years of age, but no further development of resistance at 3.7 or 4.7 years of age. Significant differences were reported between progeny of the two sires.

Hazel and Terrill (1945, 1946, 1946*a*) and Terrill, Sidwell and Hazel (1946) have demonstrated the significance of environmental effects i.e., sex, twinning, age of dam and inbreeding in masking the expression of quantitative characters which are used as measures of production and economic value of sheep.

Bartlett (1947) presented a resume of the use of transformations, including the theoretical variances to be expected with each. Emik (1947) showed that the square root transformation was most appropriate for analysis of variance of trichostrongylid infestation levels and tested the fit of the sampling error to a Poisson distribution.

Yates (1934), Snedecor and Cox (1935), Snedecor (1946), Hazel (1947), Patterson (1947), and others have shown how proper adjustments may be made for the main effects when disproportionate subclass numbers are present, especially when interaction is not significant.

Materials and Methods

Biological

The lambs used to provide these data constituted the major portion of

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the lamb crop born at the University of California at Davis in December 1938 and the first months of 1939. There were 101 lambs of various breeds and sires as listed in table 1. Infestation was by natural means, the lambs being grazed on ladino clover throughout the experiment. Rams and ewes were carried in separate bands.

Fecal samples were collected in the morning at weekly intervals for 12 weeks beginning in June. At that time the necessity for complete sampling was not realized and as a result a number of lambs were "dry" at the time

TABLE 1. MEANS OF EGG COUNTS BY SEX, BREED AND SIRES (EGG/0.02 G. FECES)

Groups studied	Rams		Ewes		Group	
	No. of sheep	Mean egg count	No. of sheep	Mean egg count	No. of sheep	Mean egg count
Mutton Class						
Southdown	4	3.32	6	2.95	10	3.10
Shropshire	5	1.72	7	1.65	12	1.68
Hampshire-Moncrieffe	9	3.15	8	2.36	17	2.92
Hampshire-Brownell	6	2.16	13	2.13	19	2.14
Class total	24	2.60	34	2.21	58	2.37
Wool Class						
Merino—899	9	2.71	7	0.97	16	1.86
Merino—317	3	0.80	1	0.77	4	0.80
Rambouillet	11	3.79	12	1.50	23	2.49
Class total	23	2.92	20	1.28	43	2.09
Total	47	2.76	54	1.83	101	2.24

of collection. The samples were placed in moist jars after being wrapped in onion-skin paper. After 24 hours of refrigeration at 40° F., to allow some equilibration of water content, the samples were prepared and counted according to the Stewart, Miller and Douglas (1937) modification of the Caldwell method.

Statistical

These data consist of integers (actual number of eggs counted) obtained from duplicate dilution counts. Bartlett (1947) has shown that such data are usually properly transformed by using the square root of the count. The variance of $\sqrt{x}$, or $\sqrt{x+0.5}$ for means of less than 10, is stabilized and analysis of variance becomes possible. Emik (1947) demonstrated the application of the method to counts of trichostrongylid eggs.

Missing items were supplied within each sex-breed group following Yates' modification of the method of Allen and Wishart as presented in Snedecor (1946).

Analysis of variance, and adjustment of mean squares for disproportionality were made according to methods presented in Snedecor.

Estimates of heritability were calculated from the formulae given by Hazel and Terrill (1945).

Results and Discussion

A preliminary analysis was made to estimate the sampling variance. The variance was 0.1706 with 1125 degrees of freedom and a mean of 0.93. The theoretical variance of a mean of 1.0 using the $\sqrt{x+0.5}$ transformation is 0.160. Agreement was tested by the Chi-square method, using a factor of 6.25 to adjust the theoretical variance to 1.0. Chi-square was accordingly $\sqrt{2\times 6.25\times 191.9706}$ (error sum of squares) $-\sqrt{(2\times 1125)}-1$ with a unit deviation. The value of 1.563 denotes a probability greater than 0.1. Remainder, or experimental error, with a mean square of 0.2255 and 1107 degrees of freedom, was highly significantly greater than sampling error. These results indicate that the sampling and counting technique was reliable, but that other factors contributed significantly to the experimental error. For the main analysis $\sqrt{x+0.5}$ was used, where x was the sum of the two counts from a sample.

Table 1 presents reconverted mean square roots of counts, expressed as eggs per 0.02 gram. The means for sex, breed, sire, class of sheep, and combinations of these main effects are given. Preliminary analysis of variance is given in table 2, where the data have also been split by sex and by mutton and wool class.

Remainder, which is Sheep × Weeks corrected for the other variables, is the best estimate of experimental error and the proper term for testing Sheep and Weeks, which were highly significant in all phases of the analysis. Sheep (within sex and breed-sire), being significantly greater than error, in turn becomes the proper error term for testing the next orders of results. For all data, the interactions of Sex × Breed, Sex × Breed-sire and Sex × Class were highly significant. Within the mutton class Sex × Breed-sire was not significant, but within the wool class it was highly significant. Sex, Breed-sire and Sire were highly significant and Breed was significant for all data. In the mutton class there was no sex difference, whereas the converse was true for the wool class. Class was highly significant in the females, but not in the males. Breed and Breed-sire were significant or highly significant in all four sub-divisions of the data. Sire differences were highly significant only for the males.

TABLE 2. ANALYSIS OF UNADJUSTED DATA, COMPLETE, AND BY SEX AND CLASS

Source	All data		Males		Females		Mutton		Wool	
	Degrees of freedom	Mean square	Degrees of freedom	Mean square	Degrees of freedom	Mean square	Degrees of freedom	Mean square	Degrees of freedom	Mean square
Total	1174		545		628		649		524	
Sheep	102	1.983**	47	1.949**	54	1.608**	57	1.600**	44	2.473**
Weeks	11	5.652**	11	2.384**	11	4.838**	11	9.166**	11	0.953**
Sheep×weeks	1061	0.423–	487	0.426–	563	0.445–	581	0.474–	469	0.321–
Sex	1	23.753**	—	—	—	—	1	2.141	1	35.982
Class	1	2.182	1	1.185	1	15.637**	—	—	—	—
Breed	4	5.980*	4	5.436**	4	6.007*	2	5.925*	1	9.896**
Breed-Sire	6	5.599**	6	6.084**	6	4.063**	3	5.139*	2	8.004**
Sire	2	9.679**	2	7.379**	2	0.174	1	3.567	1	6.112
Twins			8	1.297**	6	3.302**	10	1.327–	14	1.636–
Sex×weeks	11	1.570	—	—	—	—	11	1.811	11	0.384
Class×weeks	11	4.467**	11	1.132**	11	3.960**				
Breed×weeks	44	1.679**	44	0.612**	44	1.799**	22	0.966	11	0.320
Breed-sire×weeks	66	1.314**	66	0.814**	66	1.237**	33	0.781	22	0.097
Breed-sire×weeks within Class	55	0.507								
Sex×class	1	14.370**								
Sex×breed	4	5.463**	—	—	—	—	2	0.258	1	6.959**
Sex×breed-sire	6	4.547**	—	—	—	—	3	0.203	2	6.146**
Sex×weeks×breed	44	0.754**								
Sex×weeks×breed-sire	66	0.604**	—	—	—	—	33	1.320**	22	0.360**
Sex×weeks×class	11	0.625**								
Sheep within Sex, Class, Breed-sire	88	1.311	40	1.348	47	1.002	50	1.461	39	1.142
Remainder	896	0.307	406	0.260	484	0.226	485	0.138	395	0.124

* Probability less than .05. ** Probability less than .01.

The Sex × Weeks interaction was not significant within the classes, but Class × Weeks was significant within the sexes. This combination points to parallel fluctuations in the mean counts of the sexes within class through time, but non-parallel fluctuations between the classes. Mean egg count was found to have no significant regression or correlation with age of the lambs, either within groups or for all data so there was no possibility of an age difference creating the difference between the two classes.

Sex and Breed-sire as well as Sex and Class constituted non-orthogonal plots with disproportionate subclass numbers. These two sets of data have been adjusted to give better estimates of the interaction and the main effects for these two cases. The results are given in table 3.

TABLE 3. DATA FROM TABLE 2 ADJUSTED FOR DISPROPORTIONATE SUBCLASS NUMBERS

Groups studied	All data		Mutton		Wool	
	Degrees of freedom	Mean square	Degrees of freedom	Mean square	Degrees of freedom	Mean square
A. Sex and breed-sire						
Sheep	89	1.321	50	1.461	39	1.142
Sex×breed-sire	6	3.735*	3	1.336	2	3.462
Sex	1	28.622**	1	1.415	1	44.818**
Breed-sire	6	6.410**	3	4.897*	2	124.212**
B. Sex and class						
Sheep	99	1.646				
Sex×class	1	12.264**				
Sex	1	21.773**				
Class	1	3.735				

* Probability less than .05. ** Probability less than .01.

Sex×Breed-sire interaction was significant for all data, but not for mutton or wool classes. The mean squares for main effects were accordingly calculated by methods appropriate for the presence or absence of interaction (Snedecor, 1946). Sex was highly significant for all data and wool class but not for mutton class. Breed-sire was significant in all cases. Sex × Class was highly significant, as was Sex, but Class was not significant. The only differences from the unadjusted analysis are the reduction of Sex × Breed-sire in all data to the significant level and in the wool group to non-significance. Disproportionate numbers have accordingly been responsible for only slight changes in overall interpretation.

Heritability was estimated by the half-sib method. Adjustments were made for disproportionate numbers, sex and twins. Heritability was found

to be $.22 \pm .41$ for Hampshires and $.25 \pm .21$ for Merinos. For males, the Merinos were 2.54 ± 1.67 and the Hampshires were $.74 \pm 1.25$. No figure was available for Merino ewes, but Hampshire ewes gave a negative value.

Data from 17 Hampshire ewes born in 1938 to the same two sires as above gave a heritability of 2.24 ± 0.30. The data of Gregory, Miller and Stewart (1940) for nine ewes born in 1937 to two different and also unrelated sires gave a negative heritability. There are too many uncontrolled variables between years to try to completely account for the differences. The relationships of the ewes between sire-groups and to a common ancestor would indicate that the dams, rather than the rams, were the influential parents. Four of these dams produced lambs from one sire in 1938 and from the other in 1939 (two in each way). Elimination of lambs resulting from these matings had little effect on means but would change the heritability to a positive value for the 1939 data. In this connection it was of interest to note that the average relationship between sire-groups was higher in 1939 (.044) than in 1938 (.024) and elimination of the cross-mated ewes would have raised the relation to .056.

Discussion

Statistical control of the sampling was adequate, but complete sampling is desirable and rather easily obtainable. No control over the number of individuals was exercised as regards sex, class, breed or twinning. Since these data can be regarded as proportional in numbers only for the population afforded by these data, disproportionate numbers must be regarded as the true condition. Equal or truly proportional numbers will be necessary to obtain optimum statistical reliability.

The distributional error agreed with the theoretical Poisson variance, substantiating the validity of the square root transformation of the data. Previous data, Emik (1947), with lesser numbers, was unable to do so.

Samples through time were not random estimates of the same population of eggs, but of a dynamic population changing through time, yet following no definite time regression. Stewart and Douglas (1937) showed that seasonal environmental changes were largely responsible for such fluctuations. The curves through time were parallel for the two sexes and for breeds within classes, but not for classes of sheep. The obvious physiological and psychological differences between these two classes of sheep may be related to their differences in expression of infestation through time.

The effects of sex in the expression of resistance are noteworthy. While the basic causes of the differences are not evident, it would appear from these data that males are rather uniformly susceptible, in comparison to females.

The females in the wool class had significantly lower means than either the males in the wool class or the females in the mutton class. Breed differences were highly significant for males and only significant for females. The nature of these differences would be an important factor in a selection program for resistant sheep. Since rams and ewes were in separate bands, the generally lower means for ewes might be influenced by pasture differences, but the interaction of sex and class would tend to preclude such an explanation.

The highly variable estimates of heritability obtained here do not preclude a strong genetic control of resistance. The matings in the flock were essentially random matings in a non-inbred group, with a consistent introduction of sires. Such matings would tend to produce pronounced variability among individuals and low variability among sire-groups. Heritability based on dam-offspring regressions should give the most reliable estimates for such a population. Quantitative and qualitative experimental control over infestation might prove to be important in reducing the variability due to meteorological influences.

The use of phenothiazine and improved methods of use of pasture along with other improvements in management, have ameliorated the immediate need for resistant sheep but, genetic resistance, established through selective breeding, is considered by some parasitologists as essential in the improvement of breeds for production, where trichostrongylidoses are a problem.

Summary

Counts of Trichostrongylid eggs were made at weekly intervals for 12 weeks on fecal samples from 103 lambs constituting most of the 1939 lamb crop at the University of California, Davis. The mean square roots of counts were used as estimates of resistance to infestation.

The distributional variance agreed with a theoretical Poisson variance, confirming the validity of using the square root transformation for these data. The experimental error, Sheep × Weeks, was significantly greater than the distributional error. Weeks of sampling and individual sheep differences were highly significant.

Sheep, adjusted for other variables, was the appropriate error term for effects not involving time. The main effects of Sex, Breed and Sire showed significant differences while Class (mutton or wool) was not significant.

Sex × Weeks and Breed-sire × Weeks, within class, were non-significant. Sex × Breed and Sex × Breed-sire were not significant within the mutton breeds. All other interactions were highly significant. Sex × Breed-sire lost significance when adjusted for disproportionality.

The interaction of Sex and Class was significant. Females in the wool class

were significantly more resistant than either the males in the wool class or the females in the mutton class. Males and females were not significantly different in the mutton class.

Heritability by the half-sib correlation was $.22 \pm .41$ for two Hampshire sires and $.25 \pm .21$ for two Merino sires. Heritabilities for only the males were $.74 \pm 1.25$ and 2.54 ± 1.67 respectively. The Hampshire females gave a negative value and no value was available for the Merinos. Hampshire ewes from the same sires in 1938 gave a figure of 2.24 ± 0.30.

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EFFECTS OF DILUTION ON MOTILITY OF BULL SPERMATOZOA AND THE RELATION BETWEEN MOTILITY IN HIGH DILUTION AND FERTILITY[1]

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MILOVANOV (1934) showed that 1 percent sodium chloride had a toxic effect on spermatozoa and utilized this fact in evaluating sperm by determining the amount of solution necessary to be added to semen to arrest the progressive motility of spermatozoa. The so-called "destructive" effect of the 1 percent sodium chloride may be a combined effect of both the hypertonicity of the solution and the high rate of dilution. The effect of dilution with more physiological solutions has been reported by Salisbury *et al.* (1943) who studied the motility of bull spermatozoa stored at 5° C. They showed that the motility of stored sperm decreased for each increase of dilution rate with yolk-citrate from 1:1 to 1:32.

The purposes of the present study are (1) to determine whether the motility of bull spermatozoa shown in high dilutions (or "resistance" to dilution) is characteristic of different semen samples or samples from different bulls, (2) to study something of the nature of the dilution effect upon sperm and (3) to seek possible correlations between fertility of spermatozoa and their motility in high dilution.

Material and Methods

Six semen samples were studied from each of 5 bulls; two ejaculates were obtained and pooled for each sample. Two diluents were used to dilute the semen, 0.9 percent sodium chloride and 0.08 M sodium citrate (28.56 gm. $Na_3C_6H_5O_7 \cdot 5\frac{1}{2}H_2O$ in 1000 cc. of distilled water). The 0.08 M concentration of sodium citrate was chosen because it was found in preliminary studies that this concentration was best for the maintenance of motility in bull spermatozoa. Motility of stored sperm in 10 different dilutions from 0.05 to 0.14 M sodium citrate had been studied at both 5° and 38° C. (unpublished data, University of Wisconsin).

Both the semen and the diluting solutions were brought to the temperature of 37.5° C. in a water bath. Dilutions of the semen were then made at 1:10 and also from 1:100 successively up to 1:12800. The semen was first introduced into containers of adequate size by a 0.01 cc. graduated pipette, the diluter was then added slowly, and shaken gently in order to obtain an even dispersion of the spermatozoa in the solution. All semen suspensions

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were kept in the same water bath for 30 minutes, and then visual estimates at 450 magnifications were made of the percentage of spermatozoa showing forward motion. The reliability of these estimates was enhanced by paired comparisons between 2 diluents and also between 2 successive dilutions with the same diluent.

Similar comparisons of the effects of dilution upon the motility of spermatozoa were made between 0.08 M sodium citrate solution and yolk-citrate diluter (0.133 M or 47.588 gm. $Na_3C_6H_5O_7 \cdot 5\frac{1}{2}H_2O$ in 1000 cc. distilled water plus equal parts of fresh egg yolk) with 11 semen samples from 8 bulls at different times.

The fertility data were based upon 337 inseminations made from the 30 samples of semen of the 5 different bulls. Of these inseminations, 165 were made on the day of semen collection and 172 on the following day. Fertility was determined by manual pregnancy examination[2] of the cows that had not been reported for re-breeding by 34–48 days after insemination with test semen. The method used was that of Wisnicky and Casida (1948) which involves the palpation and recognition of the amniotic vesicle as it lies in the uterine horn.

Results and Discussion

Dilution effects of sodium chloride and sodium citrate diluents upon motility of bull spermatozoa.

The percentage of motile spermatozoa decreased markedly in the higher dilutions of either diluent (table 1). There was a mean difference between the two diluents when all dilutions were considered, the motility averaging higher in sodium chloride than in sodium citrate solution. The differences in motility among the 8 dilutions and also between the 2 diluents were highly significant. However, the variability between samples was also highly significant; this was true between the averages of the different bulls as well as between the averages of different samples from the same bull (table 2).

The significant interactions between diluent and sample and between dilution and sample indicate that the sperm in different samples of semen reacted differently in different diluents and also in different dilutions. Further breakdown of "sample" into "sample within bull" and "sample between bulls," showed highly significant interactions between "diluent and sample" in both cases. This indicates that the difference between the diluents was more marked for some bulls and some samples than for others.

In spite of the fact that the motility shown in 0.9 percent sodium chloride averaged higher than in the sodium citrate solution, the spermatozoa

[2] The authors wish to express their indebtedness to Mr. Clee A. Lloyd who made the pregnancy examinations.

TABLE 1. AVERAGE PERCENTAGE OF MOTILITY AND HIGHEST DILUTION SHOWING MOTILITY OF BULL SPERMATOZOA IN A DILUTION OF 1:10 AND 8 SUCCESSIVE DILUTIONS FROM 1:100 TO 1:12800 OF SODIUM CHLORIDE AND SODIUM CITRATE SOLUTIONS

Bull	Diluent	Dilution									Av. of 8 dilutions (from 1:100 to 1:12800)		Av. highest dilution showing motility		Av. no. of dilutions showing motility (1:100 to 1:12800, 8 dilutions)	
		1:10	1:100	1:200	1:400	1:800	1:1600	1:3200	1:6400	1:12800	All dilutions	All dilutions, both diluents	Each diluent	Both diluents	Each diluent	Both diluents
M	NaCl	64.1	55.0	50.0	39.2	30.8	21.7	8.5	3.0	0	26.0	24.0	5467	6590	6.5	6.7
	NaCit.	62.5	55.0	48.3	39.2	20.0	7.3	5.3	2.0	0.3	22.2		7713		7.0	
EP	NaCl	61.7	55.8	47.5	31.7	21.2	13.5	11.7	5.0	1.7	23.5	20.8	4933	5000	5.5	5.9
	NaCit.	59.2	48.3	44.2	32.5	15.0	3.0	1.7	0.5	0.3	18.2		5067		6.3	
BB	NaCl	69.2	58.3	54.2	40.2	33.3	23.5	13.5	5.2	1.7	28.7	25.6	5400	7233	6.2	6.7
	NaCit.	66.7	54.2	45.8	34.7	23.5	10.2	6.3	3.0	2.2	22.5		9067		7.3	
J	NaCl	69.2	50.8	43.3	29.7	21.2	14.2	5.2	1.8	1.7	21.0	22.2	5200	7133	5.7	6.5
	NaCit.	65.8	52.5	49.2	38.3	28.3	9.3	6.2	3.0	1.2	23.5		9067		7.3	
UN	NaCl	74.2	65.8	61.7	55.8	42.5	35.0	20.0	8.8	1.8	36.4	32.5	8533	10133	7.3	7.5
	NaCit	66.7	60.0	50.0	44.2	31.7	18.3	15.0	7.0	2.8	28.6		11733		7.8	
All bulls	NaCl	67.7	57.2	51.3	39.3	29.8	21.6	11.8	4.8	1.4	27.1		5907		6.2	
	NaCit.	64.0	54.0	47.5	37.8	23.7	9.6	6.9	3.1	1.3	23.0		8533		7.2	
All bulls both diluents		65.9	55.6	49.4	38.5	26.7	15.6	9.3	3.9	1.3		25.0		7200		6.7

TABLE 2. ANALYSIS OF VARIANCE OF MOTILITY OF BULL SPERMATOZOA IN 8 DILUTIONS (FROM 1:100 TO 1:12800) OF SODIUM CHLORIDE AND SODIUM CITRATE SOLUTIONS

Source of variation	D/F	Mean square	F
Total	479		
Diluent	1	2058	31.18**
Dilution	7	26182	396.70**
Sample	29	1789	27.11**
Diluent×Dilution	7	206	3.12**
Diluent×Sample	29	518	7.85**
Dilution×Sample	203	116	1.76**
Diluent×Dilution×Sample	203	66	
Further breakdown of "Sample"			
Sample between bulls	4	1988	30.12**
Sample within bull	25	1757	26.62**
Diluent×Sample bet. bulls	4	383	5.80**
Diluent×Sample with. bull	25	540	8.18**
Dilution×Sample bet. bulls	28	78	1.18
Dilution×Sample with. bull	175	122	1.85**

** $P < .01$.

showed a greater resistance to dilution with sodium citrate solution than with the 0.9 percent sodium chloride solution. This is indicated by the greater average magnitude of the "highest dilution showing motility" in the sodium citrate solution (table 1). This could have been due to the stimulating but injurious effect of sodium chloride as reported by the Russian workers (Milovanov, 1933; Selivanova, 1934).

Nature of the dilution effect

It was questioned whether highly diluted spermatozoa could regain their motility upon the removal of the diluent. This was emphasized because rabbit sperm which no longer showed forward motion because of high dilution had shown some fertility when used in artificial insemination (Cheng and Casida, 1948). Bull semen was diluted in 0.08 M sodium citrate up to a rate where no motility was observed, the suspension was then centrifuged and the sperm reconcentrated into a very small volume. The recovered dense suspension was kept at 37.5° C. for 30 minutes, but no motility was regained in any of the 3 separate trials that were made.

It has been suggested that spermatozoa in low concentrations are harmed

by oxygen (Salisbury, 1946). The motility of highly diluted spermatozoa was thus compared when diluted in air and when diluted under vacuum. A series of dilutions was made in 0.08 M sodium citrate (1/100 to 1/16000) but in 3 different trials no significant or consistent difference of motility was observed between samples diluted under aerobic and anaerobic conditions.

An increase in the ability of bull spermatozoa to withstand cold shock when diluted with yolk-phosphate buffer was reported by Lasley, Easley and Bogart (1942). The possibility that egg yolk when mixed with a citrate solution might have a protective effect against high dilution was tested because of the possibility that its insulating properties against adverse environmental factors might be somewhat general.

TABLE 3. AVERAGE PERCENTAGE MOTILITY OF BULL SPERMATOZOA IN A DILUTION OF 1:10 AND 8 SUCCESSIVE DILUTIONS FROM 1:100 TO 1:12800 OF 0.08 M SODIUM CITRATE AND YOLK-CITRATE

Dilution	Percentage motility in	
	NaCit. sol.	Yolk-Cit. sol.
1: 10	65.9	71.8
1: 100	52.3	71.4
1: 200	50.5	71.8
1: 400	43.3	66.4
1: 800	32.4	61.4
1: 1600	21.8	48.6
1: 3200	11.0	41.8
1: 6400	3.6	34.1
1:12800	0.8	26.8
Av. of 8 dilutions (from 1:100 to 1:12800)	27.0	52.8

The percentage motility of the sperm diluted in yolk-citrate averaged almost twice as high over the 8 dilutions from 1:100 to 1:12800 as it did in sodium citrate solution (table 3). No change was noted in motility of sperm in the yolk solution as dilutions were increased from 1:10 up to 1:200. Beyond that there was a decrease but all samples still showed motility at 1:12800 as compared to only 5 out of 11 in the sodium citrate solution at that dilution. The isolation of a fraction of yolk particularly responsible for protection against cold shock was reported by Mayer and Lasley (1945); the ability of this fraction to protect sperm against high dilution should also be studied.

The effect of dilution upon the motility of spermatozoa is tentatively viewed as due to the leaching of a substance or substances important to the

motility and life of the spermatozoa. The higher the dilution, then the greater would be the loss of this substance from the sperm cells, and this is in accord with the observation that the greater the dilution the less the motility. Further, reconcentration of the highly diluted sperm by centrigugation would not be expected to reconcentrate the leached substance with the sperm so as to reactivate them. Finally the rates at which this substance might be leached from the cell might be expected to differ with the character of the diluting solution. The greater resistance of sperm to dilution with yolk-citrate than with sodium citrate solution thus is also in accord with this idea.

That this substance is primarily a constituent of the sperm and not of the seminal fluid is indicated by the fact that sperm may be washed and retain their motility (Lardy and Phillips, 1941). Tentatively it is assumed that the necessary constituent is not leached from the sperm by the washing because of the small amount of fluid to which the sperm is exposed relative to the amount used in the high dilutions. This assumption needs to be tested further by a study of motility of washed sperm where total volume of fluid is great from repeated washings but the volume for any one washing is small and the sperm concentration is kept high.

Relation between motility in high dilution and fertility

Three criteria of motility of spermatozoa suspended in the sodium chloride and sodium citrate solutions were used to correlate with fertility (table 4). No significant correlations were found between any of these 3 motility criteria and fertility "within bull." However, "between bulls," significant correlations were found between motility at 1:10 in sodium citrate solution

TABLE 4. CORRELATIONS BETWEEN 3 CRITERIA OF MOTILITY AND FERTILITY IN BULL SPERMATOZOA

Source of variance	D/F	Motility at 1:10		Av. motility of 8 dilutions (from 1:100 to 1:12800)		No. of dilutions showing motility (from 1:100 to 1:12800, 8 dilutions)	
		NaCl	NaCit.	NaCl	NaCit.	NaCl	NaCit.
Within bull	28	.137	−.046	−.120	−.124	−.200	.122
Between bulls	3	.868	.941*	.638	.642	.623	.876*

* P = .05 to .01.

and fertility, and also between the total number of dilutions showing motility (or the "resistance of spermatozoa to highest dilution") in the same solution and fertility. The coefficients were only of a bare significance in both instances and the fiducial limits of the correlations based on such small numbers are so great that little importance should be attached to their magnitude.

Summary

The effect of high dilution upon motility of bull spermatozoa was studied on 6 semen samples from each of 5 bulls. The semen was diluted 1:10 and also successively in 8 different dilutions from 1:100 to 1:12800. Two different diluents were used, 0.9 percent sodium chloride and 0.08 M sodium citrate. The percentage of motile sperm decreased markedly in the higher dilutions with either diluent. The average motility over all dilutions was greater in the chloride than in the citrate solution but the resistance to dilution as indicated by the maximum dilution which would support motility was greater in the citrate solution. Significant differences between the samples of semen from different bulls were observed and also between the different samples from the same bull.

Reconcentration by centrifugation of highly diluted sperm failed to restore motility. The inhibition of motility was just as great when semen was diluted in vacuum as when diluted in air. Egg yolk when added to the citrate solution gave a marked increase in the resistance of the sperm to dilution.

Possible correlations were sought between different indices of motility of the spermatozoa and the fertility of the same samples when used in artificial insemination. No significant correlations were found when studied between samples within bulls. There was, however, very slight evidence between bulls for a correlation between motility in a dilution of 1:10 and fertility and also between the highest dilution in which motility was shown and fertility, dilution in both cases being in sodium citrate solution.

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HERITABILITY ESTIMATES OF SOW PRODUCTIVITY AND LITTER PERFORMANCE[1]

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THE ability of sows to farrow large litters and to raise their pigs to market age and weight is one of the basic factors of successful swine production. If this ability is highly heritable, then selection toward the desired ideals can increase the performance of the sows.

Many studies have been made pertaining to sow prolificacy and the relation of age of sow to number of pigs farrowed. These have been reveiwed by Lush and Molln (1942), Olbrycht (1943), Stewart (1945), and Winters, Cummings and Stewart (1947). Lush and Molln in their review found estimates of heritability of litter size ranging from 0.10 to 0.44. The estimates from later studies have all fallen within this range.

The data used in the following discussion of factors relating to sow performance were gathered from the Nebraska project of the Regional Swine Breeding Laboratory. For several years before the project was started, the swine herd at the North Platte Substation had been bred as a closed herd. At the outset four closed lines were set up. Three of these (lines 1, 2, and 3) were organized as one sire lines, while the fourth (line 4) was set up as a two-sire line. This practice, however, was not rigidly adhered to, for more than one sire has been used at times in the one-sire lines. In the fall of 1938, line 3 was divided into two parts. One of these was continued as line 3, while the other was designated as line 5. At the same time line 6 was also organized. It was composed of gilts from lines 2, 3, and 4, mated with a boar from line 4. These two lines were started because they seemed to offer possibilities for improvement in type that were not entirely present in the original lines.

Management practices were held as uniform as possible throughout the period of this study (see Baker, Hazel, and Reinmiller, 1943). Diseases were not a major factor affecting production except in an isolated season or two.

The criteria used to evaluate sow performance were: the total number of pigs farrowed (F), born alive (A), alive at 21 days of age (21), alive at weaning (56), alive at 168 days of age (168). In addition to the number of pigs farrowed and raised, the total weaning weight of the litter (56 wt.) and total litter weight at 168 days (168 wt.) were also studied.

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Sow performance beyond the number of pigs farrowed may be thought of as a combination of a progeny test of the sow and a measure of her direct environmental (nutritional) influence on her litter. As the pigs become older and their own genes become increasingly important for a given character, their performance constitutes more of a measure of the transmitting ability of their dam for rate of gain and less of a measure of her direct environmental influence. Litter weight at 168 days of age may, therefore, be considered more as a progeny test of the dam for rate of gain than as a measure of her productivity, as the term is usually applied. For these reasons most studies dealing with sow prolificacy have not included litter performance beyond the weaning of the litter. From weaning time on, most studies have concerned individual pig weights and growth rates.

The object of this study was to extend the knowledge pertaining to sow performance to the time the pigs were 168 days of age, and to obtain estimates of heritability of the various ages and weights used to measure sow productivity.

Materials and Methods

Data on three groups of lines and seasons were available for the analysis of factors affecting sow performance. The first set of data was on lines 1 to 4 from the spring of 1937 through the fall of 1938. The second set was on lines 1 to 6 from the spring of 1939 through the spring of 1941. For the third group of data lines 1, 2, 5, and 6 were used for the seasons fall of 1941 to the fall of 1943, inclusive.

During the first four seasons some sows were used in the foundation of more than one lines. Also, two boars from line 1 were used to a limited extent in line 4. The data were pooled and the final analyses were made on the pooled data. The analysis of variance method given by Snedecor (1946) was used.

Complete information was secured on 561 litters. These litters were produced by 331 different sows and by 76 different sires. The 331 sows producing these litters were by 50 different boars and out of 214 dams.

The ages of the sows when they farrowed their first litter ranged from 11 to 13 months. Two litters a year were produced so that the age increment between succeeding litters for a sow averaged six months. One sow produced seven litters, farrowing her last litter when she was 48 months of age.

The percent of inbreeding varied greatly between and within lines for both the dams and the litters. For the dams the inbreeding coefficients ranged from 0 to 0.49. The inbreeding coefficients for the litters ranged from 0.01 to 0.54.

Because of the wide variation in age of sow, inbreeding of sow, and in-

TABLE 1. MEANS OF THE CHARACTERISTICS STUDIED BY LINES[1]

Line and seasons used	Litters	M	Inbreeding		Number of pigs					Litter weight	
			D_x	L_x	F	A	21	56	168	56 wt.	168 wt.
	number	*months*	*percent*	*percent*	*number*	*number*	*number*	*number*	*number*	*pounds*	*pounds*
1 S37-F43	98	15.9	23.0	28.1	8.9	7.9	5.6	4.9	4.3	156.4	688.2
2 S37-F43	132	17.0	12.2	20.5	9.1	8.2	6.4	5.7	4.9	177.5	814.9
3 S37-S41	89	15.3	12.8	22.1	9.8	8.8	6.2	5.4	4.8	171.2	851.7
4 S37-S41	74	17.0	8.0	12.3	9.0	7.8	5.7	5.6	5.0	184.4	935.0
5 S39-F43	94	18.9	22.8	29.2	9.1	8.3	6.0	5.6	4.6	188.1	762.3
6 S39-F43	74	19.2	18.4	27.0	8.8	8.0	5.9	5.4	4.6	183.2	798.5
Total or Average	561	17.2	16.2	23.4	9.1	8.2	6.0	5.4	4.7	176.2	803.2

[1] The symbols used are:
M—Age of sow in months
D_x—Inbreeding of sow
L_x—Inbreeding of litter
F—Number of pigs farrowed
A—Number of pigs born alive
21—Number of pigs alive at 21 days
56—Number of pigs weaned
168—Number of pigs alive at 168 days
56 wt.—Total weaning weight of litter
168 wt.—Total litter weight at 168 days

breeding of litter, the data were adjusted for these variables. The adjustments were made by means of multiple regressions (Snedecor, 1946).

Data and Discussion

Mean Performance of Lines

The means of the various items for the six lines are shown in table 1. Lines 1 and 2 were used for all 14 seasons; lines 3 and 4 were used for the first 9 seasons; and lines 5 and 6 for the last 10 seasons.

The boars and sows at the start of the project (lines 1–4) were, for the most part, unrelated and were not highly inbred themselves. Consequently,

TABLE 2. WITHIN LINE-SEASON SUBCLASS SIMPLE AND PARTIAL REGRESSION COEFFICIENTS OF THE PRODUCTION FACTORS ON AGE OF SOW (M), INBREEDING OF SOW (D_x), AND INBREEDING OF LITTER (L_x)

	Production factors[1]						
	F	A	21	56	168	56 wt.	168 wt.
Simple regressions							
M	$.144^{xx}$	$.121^{xx}$	$.064^{xx}$	$.082^{xx}$	$.082^{xx}$	4.56^{xx}	15.29^{xx}
D_x	$-.057^{xx}$	$-.058^{xx}$	$-.058^{xx}$	$-.068^{xx}$	$-.075^{xx}$	-3.27^{xx}	-14.03^{xx}
L_x	$-.060^{xx}$	$-.056^{xx}$	$-.053^{xx}$	$-.058^{xx}$	$-.068^{xx}$	-2.68^{xx}	-14.68^{xx}
Partial regression							
$M \cdot D_x L_x$	$.141^{xx}$	$.114^{xx}$	$.045^{xx}$	$.063^{xx}$	$.058^{xx}$	3.78^{xx}	10.41^{xx}
$D_x \cdot ML_x$	.011	$-.001$	$-.027$	$-.030$	$-.037$	-1.24	-6.39
$L_x \cdot MD_x$	$-.027$	$-.027$	$-.038$	$-.036$	$-.045^{x}$	-1.44^{x}	-10.57^{xx}

[1] See footnote Table 1 for deacription of symbols.
$x = P \leqq .05$, $xx = P \leqq .01$.

the percentage of inbreeding in the litters increased rather slowly for the first few seasons. Lines 5 and 6, on the other hand, were started in the spring of 1939. While the boars and sows in these lines were not highly related to each other, they were about 20 percent inbred themselves. After the first litters were produced, the percentage of inbreeding in lines 5 and 6 was almost as high as it was in lines 1 to 4.

The means for the number of pigs farrowed and born alive in the six lines reflect the differences in the ages of the sows as well as the differences in the amount of inbreeding of both the sows and the litters. The variation in the mean number of pigs alive at the later ages reflects not only the differences in age of dams and the percent of inbreeding of the sows and litters, but also any differences present in mothering ability of the sows. No attempt has been made to measure the extent of this factor in the present data.

Influence of Age of Sow and Inbreeding of Sow and Litter

The simple and partial regression coefficients of each of the productivity factors on age of sow, inbreeding of dam, and inbreeding of litter are given in table 2. All the simple regression coefficients are statistically highly significant ($P < .01$). Only ten of the partial regression coefficients, on the other hand, are statistically significant.

Within the limits of these data the partial regression coefficients in Table 2 indicate that for each 10 percent increase in inbreeding litter size at 168 days might be reduced by 0.45 pig for inbreeding of the litter and 0.37 pig for inbreeding of the dams. Inbreeding of the dam and litter, however, account for only a small portion of the variation in litter size and weight within a line-season subclass, simply because the variation in degree of inbreeding within such subgroups is small compared with the total possible range of variation. Age of sow, on the other hand, varies about as much within line-season subclasses as it does between such subclasses.

The inbreeding of the dam and litter, while not very important in determining the size of the litter raised, exerted more influence on the litter weights. The effect of inbreeding of the litter on litter weight is in line with the findings of Baker *et al.* (1943) and Nordskog, Comstock and Winters (1944). They showed that the pig's own heredity becomes more important as the pig grows older.

The age of the sow was the most important factor in determining the size of the litter farrowed and the number of pigs born alive. As the pigs became older, environmental influences became stronger, relative to the importance of either M, D_x, or L_x. Age of sow, however, was still more important in determining the number of pigs alive at 168 days than was either the inbreeding of the dam or litter.

Lush and Molln (1942) found that age of sow was an important factor in determining both the size of the litter farrowed and weaned, as well as the weaning weight of the litter. This effect on litter weight was primarily due to the fact that the older sows farrowed and raised more pigs.

The present data are in agreement with those of Stewart (1945) in that both show the age of the sow to be more important in determining the total size of the litter farrowed as well as the number of pigs born alive than either the inbreeding of the dam or litter.

The simple regression coefficients agree with Stewart's data with respect to the relative importance of the inbreeding of the sow in relation to inbreeding of the litter. The present data, as well as the data of Stewart, do not agree with the findings of Hetzer, Lambert and Zeller (1940). These workers found that inbreeding of the litter was more important than inbreeding of the dam in influencing litter size at birth, 28 and 70 days of age.

Dickerson, Lush and Culbertson (1946) studied the effect of inbreeding of the litter in relation to viability and growth rate. They found that litter size decreased from 0.26 to 0.39 pig from birth to 154 days of age for every ten percent increase in inbreeding. The corresponding partial regressions given in Table 2 are in close agreement with their findings on litter size. With respect to litter weight, Dickerson *et al.* found that weaning weight of the litter decreased 15 pounds and 154 day weight decreased 79 pounds for each ten percent increase in inbreeding of the litter. In the present data the corresponding values are 14.4 pounds for weaning weight and 105.7 pounds for 168 day weight.

Whatley (1942) found that age of the sow did not have a statistically significant effect on individual 180 day weight in Poland China swine. The trend of his data, however, favored the pigs produced by the older sows. He also found that the inbreeding of the litter had almost the same effect on 180 day weight regardless of whether the pigs were considered individually or whether the litter was taken as the unit of measure. The effect of the dam's inbreeding was negligible in his data. The present data on 168 day litter weight agree fairly well with the results found by Whatley for 180 day weights.

Baker *et al.* (1943) found that as the pigs became older their own hereditary makeup became increasingly important in determining growth rate and hence weight for age. The results of Nordskog *et al.* (1944), while not in complete agreement with those of Baker *et al.*, did show that the age-of-sow effects on individual pig weight become less important as the pigs increase in age. In general, the present data agree with these findings.

Line and Season Differences

The data for the three groups of line-seasons were adjusted for age of sow inbreeding of sow and litter by means of multiple regression. The within line-season subclass partial regression coefficients were used for these adjustments. It is realized that the adjustment for age of sow removes only the linear effects of age. A small amount of bias is probably still left in the data for one sow was used till she was 48 months old.

After each group of lines and seasons had been adjusted, the data were pooled. The results of this pooled analysis showed that the differences between the lines and seasons were statistically insignificant.

Heritability of Sow Performance

Heritability estimates were determined by calculating the repeatability of litter size and weight as well as by doubling the intra-sire regression of daughter's record on dam's record. These estimates were based on data

secured from all of the available records from the spring of 1937 to the fall of 1947, inclusive.

Data from 239 sows were available on which repeatability of litter size and weight could be determined. These sows were a select group. In the first place, they had been saved to produce a second litter because of the good performance of their first litter. In the second place, a number of sows that had two or more litters could not be used, for either the first or the second litter was farrowed in a line cross or a top cross. These crosses have not been included in the present study. The within sire regression coefficients of second litter on first litter are given in table 3.

Lush (1940) showed that heritability could be estimated by doubling the intra-sire regression of offspring on dam. All the additively genetic variance, about half the epistatic variance and from none to one-fourth of the dominance deviations are measured by this method. Furthermore, Lush and Straus

TABLE 3. HERITABILITY ESTIMATES OF SOW PERFORMANCE[1]

Heritability estimated from	F	A	21	56	168	56 wt.	168 wt.
Intra-sire regression of daughter on dam	0.251	0.237	0.199	0.189	0.418	0.212	0.019
Repeatability of sow performance	.235	.212	.341	.246	.317	.533	.341
Average	.243	.224	.270	.218	.368	.372	.180

[1] See footnote table 1 for description of symbols.

(1942) state that this method of estimating the heritability of a character seems to be the most dependable for data like these.

For this analysis 528 daughter-dam pairs were available. Here, as in the repeatability analysis, cross-line litters produced by either the dam or daughter eliminated a number of pairs. A number of dams had several daughters in this comparison and 31 of the 101 sires were used more than once. Each dam was considered separately and her record was repeated for each daughter she had in a sire group. The intra-sire regression coefficients are also given in Table 3.

The regression based on repeatability of sow performance was significant for litter weight at weaning, and approached significance for A, 21, and 168. With respect to the intra-sire regressions, only 168 was significant. Since the number of dam-daughter pairs per sire varied from 1 to 17, it is not surprising that the standard errors for these coefficients were large.

The limitations of the present data are caused in large part by the small size of the sample used with its accompanying large sampling errors. In spite

of these limitations, it of is value to see how these estimates compare with those that have been previously determined by other workers.

With respect to total number of pigs farrowed, the present heritability estimates of 0.25 and 0.24 fall within the range of those published previously. As reported by Lush and Molln (1942) in their review, these range between 0.10 and 0.44.

For number of pigs born alive, Stewart (1945) reported a mean estimate of 0.136. The present estimates were 0.24 and 0.25 with a mean of 0.24. Hetzer *et al.* (1940) reported a correlation between litters from the same sow for litter size at 28 days of 0.16. The corresponding figure for the present data is 0.34 for litter size at 21 days. The average estimate of heritability for litter size at this age was 0.27.

The previous estimates for heritability of litter size at weaning ranged from 0.17 (Lush and Molln) to 0.32 (Cummings, Winters and Stewart, 1947). The current estimates range from 0.19 to 0.25 with a mean of 0.22. No previous reports on litter size at 168 days have been found. For the present data, these were 0.42 based on intra-sire daughter on dam regression and 0.32 based on repeatability of sow performance.

For litter weight at weaning, the average of the present estimates, 0.37, is higher than those previously reported.

The heritability estimates on litter weight at 168 days of age averaged 0.18 with a range from 0.02 to 0.34. The average of these two estimates agrees fairly well with the heritability estimates based on individual pig weights found by other workers (Baker *et al.* (1943), Nordskog *et al.* (1944), Krider *et al.* (1946).

As has been pointed out in the recent paper by Cummings *et al.* (1947), heritability estimates are of value in describing the population on which they have been determined. They are useful in helping devise the optimum plans for effecting improvement for they determine in part the efficiency of the plan being considered. Since heritability estimates are affected by the proportion of total variation that is due to environment, it is surprising indeed that the estimates thus far published have not shown greater disparity.

Summary

Data on 561 litters raised in the Nebraska Swine Breeding Project from 1937 through 1943 were used to study the effects of age of sow, inbreeding of sow and litter on seven sow productivity and performance factors. The seven factors studied were: total number of pigs farrowed; number of pigs born alive; number of pigs alive at 21, 56, and 168 days of age; total weight at weaning, and 168 days of age.

From the simple within line-season subclass regressions it was found that

age of sow was more important than either inbreeding of the sow or litter in affecting sow productivity and performance. The standard partial regressions also indicate that age of sow was the most important factor affecting the sows' performance, but inbreeding of the litter became increasingly important as the pigs grew older.

Heritability of the factors measuring sow productivity and performance were estimated from intra-sire regression of daughter on dam and regression of a sow's second litter on first litter. The average of these estimates was for total number of pigs farrowed, 0.24; for number of pigs born alive, 0.22; for number of pigs alive at 21 days, 0.27; alive at 56 days, 0.22; alive at 168 days, 0.37; for litter weight at weaning, 0.37; and for litter weight at 168 days, 0.18.

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THE VITAMIN A AND VITAMIN C CONTENT OF SOWS' COLOSTRUM AND MILK

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STUDIES of the gross composition of sows' milk have been reported by various workers over a period of years. However, the data published on the vitamin A and vitamin C content of sows' milk are very limited. Braude *et al.* (1947) in England reported on the composition of milk from 9 Large White sows. Their mean values for colostrum were: 30.6 ± 2.0 mg. of ascorbic acid per 100 ml., and 71.1 ± 9.1 I.U. of vitamin A per g. of fat. For milk they reported mean values of 13.0 ± 0.3 mg. of ascorbic acid per 100 ml. and 11.0 ± 0.4 I.U. of vitamin A per g. of fat. The same group of workers, Braude *et al.* (1946) reported on 18 samples of sows' colostrum in which they obtained mean values of 23.8 mg. per 100 ml. for vitamin C and 347 I.U. per 100 ml. for vitamin A.

The above values were obtained from milk which was expressed by an injection of Pitocin. Earlier work by Benham (1943) gave vitamin A values ranging from 291 to 564 γ/100 ml. of colostrum on the first day of lactation Schofield *et al.* (1942) found the vitamin A content of sows' colostrum was higher than that in later milk. The values of the latter authors are similar to those of Braude *et al.* (1947).

Experimental

The data presented in this paper are the results of the analyses for vitamin A and vitamin C levels of milk from 20 sows. Sows of the Poland China and Chester White breeds were used in this experiment. The 10 sows on pasture were 5 Poland China and 5 Chester White, while the 10 sows in dry-lot were all Poland Chinas. All sows whose milk was sampled were in either their first or second lactation period.

The sows in the first lot were carried through growth, gestation, and lactation on a grain ration supplemented with animal protein and had access to pasture until shortly prior to farrowing. The sows in the second lot were fed during growth, gestation, and lactation on a grain ration supplemented with plant protein and 5 percent alfalfa. They were confined to dry-lot during this entire period.

The farrowing dates for the sows in the pasture group ranged between September 24 and October 11, 1947, and the sows in the dry-lot group farrowed between November 12 and December 26, 1947.

[1]The authors wish to acknowledge the assistance of Li-min Wu in the vitamin A determinations.

[2] From the Animal Husbandry and Biochemistry Departments. Approved for publication by the Director of the Wisconsin Agricultural Experiment Station.

The number of pigs farrowed and the number weaned is included in table 1. A very mild outbreak of diarrhea occurred which, in rather serious degree, has been prevalent in the herd for the past several years.

The sows were all milked on the day of parturition, as soon after farrowing as possible, then on the third day, the first week, and each subsequent week thereafter until weaning the litters at 8 weeks of age. They were snubbed by means of a running noose on their upper jaw for the purpose of milking. To obtain a letdown of milk the sows were injected intravenously in an ear vein with 1 ml. of Pitocin (Parke, Davis and Co.) which contains 10 international units of the oxytocic principle of the posterior lobe of the pituitary gland. Ely and Petersen (1941) devised this method for inducing the letdown of milk in the cow and a similar method was employed by Braude *et al.* (1947) for induction of milk letdown in the sow. After a few seconds, two milkers, one on each side of the sow, manually expressed the milk from the udder into amber colored bottles. The effect of the Pitocin remained for from 4 to 8 minutes, and the amount of milk obtained was usually about 250 ml. If time did not permit complete milking of the udder, several teats were milked completely dry to assure a representative sample. Machine milking has been attempted but has not yet proved satisfactory.

The vitamin A was determined according to a slight modification of the method of Boyer *et al.* (1944). A 5 ml. milk sample diluted with 15 ml. water was used to replace the 20 ml. milk sample recommended in the method. The carotene determination was omitted on the evidence that there was no carotene present in the milk. The milk was sharp frozen immediately after milking and held until vitamin A analyses were run.

The vitamin C was determined by the method of Mindlin and Butler (1938). The use of high quality quantitative filter paper was found necessary to obtain a clear filtrate after precipitation of the protein by 6 percent metaphosphoric acid. A dilution of 1 part of the milk in 9 parts of water was first made to lower the vitamin C content to a level which could be read colorimetrically. The vitamin C determinations were made immediately after the milk was collected in amber bottles.

Results and Discussion

The results of the vitamin A and vitamin C determinations in the milk of the two lots of sows are shown in figures 1 and 2. More detailed results are given in the three tables; table 1 gives a summary of the litter size, and the vitamin A and vitamin C content of the colostrum and milk of each sow on experiment; table 2 shows the vitamin A content of the colostrum and milk; and table 3 shows the vitamin C content of the colostrum and milk.

Vitamin A

The vitamin A content of the colostrum and milk was consistently higher from the pasture-fed sows as compared to the dry-lot-fed sows. In the case of normal milk the difference was 50.6 percent while for the first and third day colostrum the difference was only 12.5 and 11.8 percent respectively. The absolute difference remained fairly constant throughout. Thus it

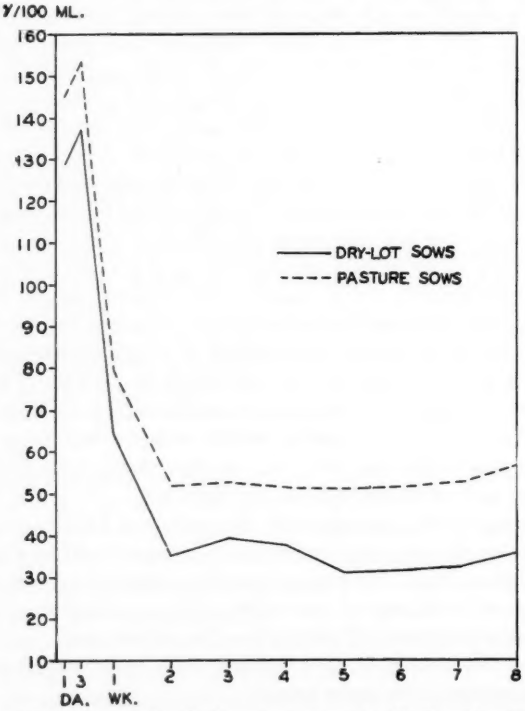

Figure 1. The average vitamin A content of sows' milk throughout lactation.

appeared that the vitamin A content of normal milk was affected more by the ration than was the vitamin A content of the colostrum.

The average vitamin A content of the colostrum was higher on the third day than the first day. This was not consistent in all sows as approximately one-half the milk samples were higher and one-half were lower on the third day. By the seventh day the vitamin A content of the milk was still one-half as high as the original colostrum. By the end of the second week the vitamin A had gone down to the same range as normal milk and remained more or

less constant until the eighth week. There was a four- to five-fold variation in vitamin A content in the colostrum and in some cases in the milk of sows on the same ration. The vitamin A content in the milk of both lots showed a gradual increase towards the end of lactation. This was not too consistent but was suggestive of a rise in advanced lactation. However, as more variation occurred within sows than between sows no definite trend can be established between the second and eighth weeks of lactation.

Vitamin C

In the case of the vitamin C content of the milk it may be seen that it was consistently higher, except at the fifth week, in the dry-lot sows as compared

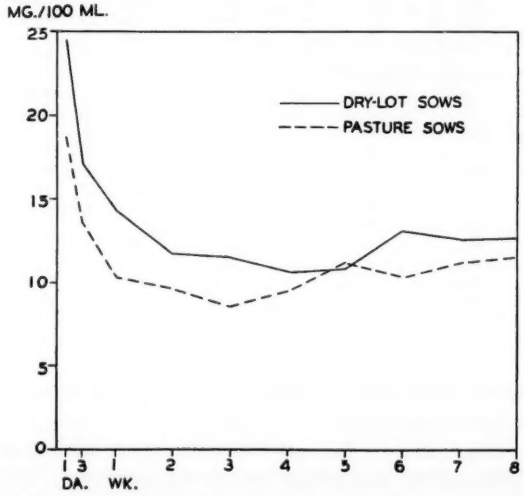

Figure 2. The average vitamin C content of sows' milk throughout lactation.

to pasture sows. The vitamin C level dropped very rapidly in both lots from the first day to the third day and by the first week had reached the range for normal milk. The vitamin C level then continued on a gradual decline reaching a low level in the third to fourth week, and then rising to a more or less constant level.

In three cases the sows became constipated and feverish following farrowing. The vitamin C level of the colostrum on the third day in these three sows was 6.7, 9.0, and 9.6 mg./100 ml. of milk as contrasted to an average of 17.1 mg. /100 ml. for the seven remaining sows in the dry-lot group. By the end of one week the sows had recovered and the vitamin C levels were again normal. On the fifth week of lactation sow No. P.C. 19 became sick.

TABLE 1. LITTER RECORDS AND VITAMIN A AND VITAMIN C CONTENT OF THE MILK OF INDIVIDUAL SOWS

Lot	Breed	Litter record		Vitamin A content		Vitamin C content	
		No. farrowed	No. weaned	Colostrum Av. 1–3 days	Normal milk Av. 2–8 weeks	Colostrum 1st day	Normal milk Av. 1–8 weeks
				γ/100 ml.	γ/100 ml.	mg./100 ml.	mg./100 ml.
Lot 1, pasture sows	C.W. 1	8	6	126.5	51.7	28.0	14.7
	C.W. 2	9	7	133.3	50.8	18.8	12.4
	C.W. 3	9	8	237.7	65.1	17.0	8.6
	C.W. 4	13	9	117.4	54.7	15.3	6.5
	C.W. 5	9	8	132.3	51.6	16.5	9.0
	P.C. 6	8	7	161.1	47.9	23.1	9.6
	P.C. 7	10	5	117.5	56.6	15.3	12.5
	P.C. 8	9	7	103.3	52.4	—	8.6
	P.C. 9	8	6	238.7	49.6	17.1	11.7
	P.C. 10	10	8	78.7	46.1	18.1	10.6
	Av.	9.3	7.1	143.6	52.7	18.8	10.4
Lot 2, Dry-lot sows	P.C. 11	9	7	142.0	40.1	27.2	10.9
	P.C. 12	8	5	132.5	35.1	24.0	11.1
	P.C. 13	5	5	207.9	37.4	22.6	9.2
	P.C. 14	9	9	113.1	25.6	25.6	13.0
	P.C. 15	8	1	95.9	39.8	16.2	15.2
	P.C. 16	6	4	131.9	26.7	25.1	11.8
	P.C. 17	8	7	116.3	28.3	26.6	13.8
	P.C. 18	9	1	151.9	49.3	—	14.3
	P.C. 19	6	4	127.2	35.2	26.8	11.2
	P.C. 20	7	5	110.4	30.7	27.1	11.7
	Av.	7.5	4.8	132.9	34.8	24.6	12.2

At that time her milk vitamin C level dropped to 4.5 mg./100 ml., far below any other sow in that group.

The vitamin C levels of each sow had quite a low variability and about a twofold difference occurred among sows on the same ration. The low point reached in each sow varied between the second and fifth week but much the larger proportion occurred on the third and fourth weeks.

TABLE 2. THE VITAMIN A LEVELS OF SOWS' COLOSTRUM AND MILK THROUGHOUT LACTATION, IN γ/100 ml.

Group	1 day	3 day	1 wk.	2 wk.	3 wk.	4 wk.	5 wk.	6 wk.	7 wk.	8 wk.
Pasture sows:										
Av.	144.8	153.3	79.4	51.4	52.6	51.4	51.1	51.6	52.9	56.8
High	254.1	331.3	154.9	77.7	77.7	66.6	61.3	71.2	77.7	86.3
Low	64.8	61.3	33.3	29.4	27.1	37.5	38.3	39.9	38.3	39.9
Dry-lot sows:										
Av.	128.7	137.1	64.1	34.9	39.2	37.6	31.1	31.5	32.7	35.7
High	166.2	300.9	151.2	72.1	63.0	63.9	51.6	48.1	70.3	71.2
Low	83.4	67.6	19.1	18.3	20.4	17.9	11.2	17.5	20.0	18.7

Discussion

The vitamin A level of sows' colostrum and early milk follows quite a different picture from that of cows. In the case of cows, the vitamin A content has gone down to a normal range by the fourth or fifth day, as reported by Stewart and McCallum (1938) and Henry *et al.* (1940). The most rapid drop occurs in the first three milkings, according to Hansen *et al.* (1946). The vitamin A level of sows' milk was still nearly double that of normal milk at the end of one week, and in the first three days no drop occurred. In fact, on an average, a rise took place between the first and third day. This agrees with the vitamin A level in human milk as reported by Lesher *et al.* (1945). The vitamin A levels for sows' colostrum and milk reported in this paper agree quite well with those reported by Braude *et al.* (1947) in England

TABLE 3. THE VITAMIN C LEVELS OF SOWS' COLOSTRUM AND MILK THROUGHOUT LACTATION, IN mg./100 ml.

Group	1 day	3 day	1 wk.	2 wk.	3 wk.	4 wk.	5 wk.	6 wk.	7 wk.	8 wk.
Pasture sows:										
Av.	18.8	13.7	10.4	9.6	8.6	9.5	11.2	10.3	11.2	11.5
High	28.0	19.0	17.2	14.7	14.0	11.9	14.5	15.9	18.6	15.4
Low	15.3	10.8	6.6	4.2	5.3	6.0	6.8	7.0	7.6	7.1
Dry-lot sows:										
Av.	24.6	17.1*	14.4	11.7	11.5	10.7	10.9*	13.1	12.6	12.7
High	27.2	21.5	20.0	16.0	16.2	13.8	13.6	15.7	15.4	17.0
Low	16.2	13.8*	11.5	8.6	7.9	8.2	7.4*	9.7	10.9	9.4

* These figures do not include the results from sick sows.

and Schofield *et al.* (1942) in Canada but are generally lower than the values for colostrum given by Benham (1943).

The relationship between the carotene level of the feed and the vitamin A level of the colostrum seems fairly limited but the milk vitamin A levels were 50 percent higher in the sows on pasture over those on dry-lot. Underwood and Curnow (1944) reported in ewes that a similar low response in vitamin A content of colostrum occurred when the carotene content of the ration was raised.

The apparent tendency of vitamin A to rise towards the end of lactation as noted here was also reported by Braude *et al.* (1947). In the case of the vitamin A in the blood of suckling pigs, the level rises between the seventh and eighth weeks, according to data of Grummer *et al.* (1948). The rise of vitamin A level in blood may be because of the general increase in vitamin A of sows' milk at this advanced stage of lactation. This rise in vitamin A might be correlated with a possible corresponding rise in fat percentage of the milk, but Braude *et al.* (1947) reported a decline in fat towards the end of lactation.

The level of vitamin A in colostrum was only three to four times as high as normal milk. This is much different from colostrum of cattle where the vitamin A content of normal milk contains 1/20 or less the initial concentration of colostrum, according to Stewart and McCallum (1938).

Two sows in the dry-lot group were milked three days after weaning and the vitamin A content of the milk showed little change from normal, averaging 38.0 γ/100 ml. for the two samples. Therefore the vitamin A in milk apparently is not destroyed by being held several days in the mammary gland.

There appeared to be no correlation between the number or the weight of the pigs weaned and the vitamin A content of the milk.

The vitamin C content as determined in sows' colostrum and normal milk is very high, the levels being approached by no other domestic animal except the mare which Pearson (1947) reports as having 11.8 mg. of vitamin C per 100 ml. of milk. Holmes *et al.* (1943) gives average figures of 2.18 to 2.69 mg. of vitamin C per 100 ml. of cows' milk, and Satterfield *et al.* (1942) gives values of 0.38 to 1.77 mg. of vitamin C per 100 ml. of ewes' milk. One report by Houston and Kon (1939) places the vitamin C level of guinea pig milk at 29.0 mg./100 ml. which would be as high as sows' colostrum. Braude *et al.* (1946) (1947) obtained average figures of 23.8 and 30.6 mg./100 ml. for colostrum and 13.0 mg./100 ml. for normal milk in sows, figures with which our data are in close agreement.

A discussion of the effect of sickness on lowering the vitamin C content of the colostrum in the sow was given earlier in the results. There may also be a correlation between unthriftiness in young pigs and the vitamin C level of the milk. One sow which lost all her litter by the end of the third day was not included in the results. In this case the vitamin C level of the milk had dropped to 1.3 mg./100 ml. on the third day. This is less than one-tenth the average for normal milk at that period. This low vitamin C level is very probably the result of infection rather than related to the cause, but is of interest.

The two sows milked three days after weaning had vitamin C levels of only 4.6 and 5.7 mg./100 ml. of milk. Therefore vitamin C is obviously destroyed by being held in the mammary gland, but again this may be because of inflammation of the udder.

The higher level of vitamin C in the milk from the dry-lot sows as compared to the pasture sows is difficult to explain. It may be partly a seasonal effect as Braude *et al.* (1947) reported a higher level of vitamin C in sows' milk in winter. However, they did not attribute this rise to a seasonal effect. The dry-lot sows in this experiment farrowed approximately two months later than the pasture sows. However, the seasonal effect did not show up

within lots where farrowing was spread over several weeks, therefore some nutritional or other factor must be involved.

As in the case of vitamin A, there is no relationship between the size and weight of litters weaned and the vitamin C level of the milk. The vitamin C level seemed to be closely correlated with the loss in weight of the sows during lactation but this awaits further study. Sows with high loss in weight during lactation showed low vitamin C in the normal milk.

No breed difference could be noticed between the Chester White and the Poland China breeds on the basis of the levels of the vitamin A and the vitamin C in their milk.

Conclusions

1. The vitamin A and vitamin C levels of colostrum and normal milk are reported for ten sows carried through growth and gestation on pasture and for ten sows carried through growth and gestation in dry-lot.

2. The sows were milked manually after the injection of 1 ml. of Pitocin, on the first day of lactation, the third day, the first week, and each subsequent week until weaning at eight weeks of age.

3. The mean values for vitamin A are: first and third day colostrum from pasture sows 143.6 γ/100 ml., from dry-lot sows 132.9 γ/100 ml.; normal milk from pasture sows 52.7 γ/100 ml., from dry-lot sows 34.8 γ/100 ml. of milk.

4. The mean values for vitamin C are: first day colostrum from pasture sows 18.8 mg./100 ml., from dry-lot sows 24.6 mg./100 ml.; normal milk from pasture sows 10.4 mg./100 ml., from dry-lot sows 12.2 mg./100 ml. of milk.

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A SYNTHETIC MILK RATION FOR BABY PIGS[1]

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ONE of the significant factors limiting hog production is the high pig mortality rate during the suckling period. Such losses constitute a problem which warranted the attention of the Livestock Advisory Committee (1947) of the United States Department of Agriculture. The committee reported that normally an estimated 33 percent of the pigs farrowed in the United States die before they are weaned. A part of these losses, the committee stated, is attributed to infectious diseases or parasitism aggravated, in all probability, by faulty nutrition. This faulty nutrition during the suckling period has direct bearing on the additional 10 percent loss between weaning and marketing.

As available information concerning the dietary requirements of suckling pigs is limited, the project briefly covered in this report was designed to provide a synthetic milk ration upon which pigs of preweaning age would respond normally and to initiate a study of various vitamin requirements of such pigs by the use of the artificial diet established.

The use of purified rations has been employed in experimental swine feeding and has been adequately reviewed by Bustad *et al.* (1948). Anderson and Hogan (1948) report raising, with some "difference in response," 3 Chester White pigs which were first allowed to nurse their mother for 3 days. These workers used an "artificial milk prepared by adding water to a synthetic diet." Duroc baby pigs 4 days of age were successfully raised by Johnson *et al.* (1947) on a "synthetic" diet composed of casein, cerelose, lard, salts and vitamins. Bustad *et al.* (1948) fed 2 groups of crossbred baby pigs a synthetic milk containing all known vitamins. One group was placed on the experiment at birth and the other when 3.5 days old. These workers were unsuccessful in raising any pig in either group beyond the twenty-first day.

In the studies reported here both growth and vitamin excretion data have been used as criteria of the adequacy of a "synthetic milk" ration for suckling pigs.

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Experimental

Four purebred Poland China litter mate baby pigs were placed on the synthetic ration when 48 hours old. This permitted the pigs to receive some colostrum.

The pigs were confined in individual metal cages that were 2.5 by 2.5 feet in size. These cages were equipped with wire bottoms (3/16 by 3/16 inch mesh), and underlying screens facilitated the collection of the feces but allowed the urine to pass into containers provided for that purpose.

TABLE 1. COMPOSITION OF RATION[1]

Components	Percent	Vitamins added	Mg. per kg. liquid milk
Casein (Labco)	30.0	Thiamine	0.65
		Riboflavin	0.65
Cerelose	37.4	Nicotinic Acid	2.50
		Inositol	26.00
Lard	26.6	Choline	260.00
		p-Aminobenzoic Acid	2.60
Salts[2]	6.0	Pteroylglutamic Acid	0.052
		Biotin	0.01
		Pyridoxine	0.65
		Calcium Pantothenate	1.30
		Alpha-tocopherol	1.00
		2-methyl-1,4-naphthoquinone	0.28
		Vitamin A	2,000 I.U./kg.
		Vitamin B	200 I.U./kg.

[1] The lard was homogenized with the solution of casein, cerelose and salts to produce an emulsion containing 13 per cent solids.

[2] Modified salt mixture of Phillips and Hart (1935).

The diet (table 1) used in this study was a modification of that described by Wiese *et al.* (1947). The water-soluble vitamins were dissolved in a 25 percent solution of ethyl alcohol, and an appropriate amount of this solution was fed in a small quantity of milk twice daily.

The pigs, on the liquid diet throughout the experimental period (56 days), were fed from nursing bottles. The pigs were fed at 3-hour intervals for the first 11 days and then every 4 to 5 hours thereafter until the termination of the experiment.

As a definite feeding schedule was followed, the animals were offered milk, at each feeding, in a quantity that approached optimal consumption.

General observations were made during the feeding period, veterinary consultations were arranged when necessary and weight records were maintained.

Individual growth rates (figure 1) as compared to the normal curve of

Ittner and Hughes (1938), plus general health and indications of well-being were the criteria used to determine the adequacy of the complete diet.

Urine samples were obtained at various intervals (table 2). Samples were filtered, the volume recorded and then analyzed for various water-soluble vitamins.

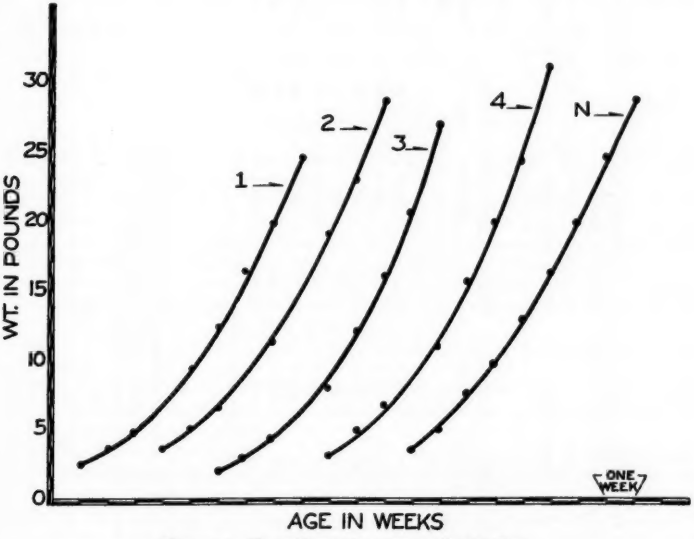

Figure 1. Growth of pigs on synthetic diet.

Results and Discussion

At the termination of the experiment the pigs on this diet were all in a healthy condition. The eyes, hair coat, skin and feet were normal, and the weights approached that portrayed by the normal growth curve of Ittner and Hughes (1938) for pigs at 56 days of age.

The urinary excretion of B-vitamins was determined at various intervals. As the intake was raised the excretion increased in proportion indicating that the pigs were receiving adequate amounts of the B-vitamins. The urinary data presented in table 2 is an average for the 4 test animals.

At the conclusion of the experiment the animals were killed and post-mortem studies were made. The quantity of subcutaneous and internal fat was sufficient to indicate normal development. A macroscopic examination of the internal organs and the nerve tissues revealed no pathological lesions, and the bones were normal and well-developed.

TABLE 2. URINARY EXCRETION OF THIAMINE, RIBOFLAVIN, PYRIDOXINE, PANTOTHENIC ACID, NICOTINIC ACID AND N[1]-METHYL NICOTINAMIDE*

Age in days	Thiamine[1]		Riboflavin[2]		Pyroxidine[3]		Pantothenic acid[4]		Nicotinic acid[5]		
	Intake, mg./day	Excretion μg./day	Intake, mg./day	Excretion, μg./day	Intake, mg./day	Excretion, μg./day	Intake, mg./day	Excretion, μg./day	Intake, mg./day	Excretion, mg./day	
										Nicotinic acid	N[1]-Methyl nicotinamide[6]
2	0.33	11.0	0.33	12.0	0.20	8.0	0.41	104.0	0.78	0.46	4.00
3					0.35	4.0	0.63	59.0	1.38	0.41	1.16
7	0.35	9.0	0.35	19.0	0.46	6.0	0.77	46.0	1.82	0.54	0.93
12	0.47	14.0	0.47	21.0	0.60	23.0	1.10	58.0	2.39	0.36	1.29
26	0.98	25.0	0.98	29.0	0.72	30.0	1.38	160.0	2.86	0.58	
36	1.46	58.0	1.46	39.0	1.37	94.0	2.51	420.0	5.46	1.32	
48	1.79	45.0	1.79	51.0	1.68	68.0	2.99	524.0	6.50	1.07	4.36
54	2.44	34.0	2.44	72.0	2.04	71.0	3.90	660.0	7.80	0.66	4.27

* Average for 4 test animals.

[1] Modified thiochrome method as described by Michelsen, Condiff and Keyes (1945).

[2] Microbiological method using L. casei as reported by Snell and Strong (1939).

[3] Yeast Microbiological assay with Saccaromyces carlsbergensis. Modification of the procedure of Atkins, Schultz, Williams and Frey (1943).
Microbiological assay using L. arabinosus based upon the procedures of Krehl, Strong and Elvehjem (1943), and Skeggs, and Wright (1944).

[5] Microbiologically with L. arabinosus using the procedures of Krehl, Strong and Elvehjem (1945) and Snell and Wright (1947).

[6] Fluorometric procedure of Huff and Perlzweig (1947).

Summary

Pigs which were allowed to nurse their mother for 48 hours have been successfully raised on a synthetic milk diet through the suckling period. The growth over an 8 week experimental period was normal and no deficiency symptoms were observed.

The urinary excretion of B-vitamins was determined and results indicate that the pigs were receiving adequate amounts of these vitamins.

In view of the above findings it is assumed that the diet presented is adequate for growing baby pigs.

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DRIED WHEY PRODUCTS IN DRYLOT RATIONS FOR WEANLING PIGS[1]

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Introduction

LIQUID whey has been utilized in swine feeding for several decades. Morrison (1937) has critically reviewed and summarized the results of the experiments in which liquid whey was fed. In a test with two lots of four pigs each, averaging 52 and 62 pounds initially, 10% "milk sugar feed" increased the gains when added to a ration of corn and tankage (New Jersey Station Report, 1931). Orr and Crichton (1923) concluded that whey solids when fed to suckling pigs as an addition to a meal ration, resulted in better utilization of the ration.

When dried whey replaced part or all of the meat meal as a supplement to wheat, the gains of bacon pigs were increased from 1.21 to 1.49 and 1.32 pounds per pig per day, respectively (Callaghan and McDonald, 1940). The most rapid gains were obtained when dried whey replaced part of the meat meal, indicating a supplementary effect of these feeds. Bünger *et al.* (1939) reported that dried whey containing 90% dry matter, 9% digestible protein, and 67–68% total digestible nutrients was successfully fed to pigs as a supplement to the regular ration provided the daily intake per animal did not exceed about 1.1 pounds of whey. Larger amounts tended to depress the appetite of the animals. It was observed that the inclusion of dried whey in the ration increased water consumption.

In the experiments reviewed, it was not stated whether the pigs were in drylot or on pasture and very few animals were used. These were either suckling pigs or were pigs weighing 50–60 pounds initially. No findings were reported on the value of dried whey or other whey products as water-soluble vitamin supplements to rations composed chiefly of corn and soybean meal for weanling pigs fed in drylot.

Experimental Procedure and Results

Experiment 1

The objective was to study the comparative value of sun-cured alfalfa meal (5%), two levels of dried whey product (4% and 8%), fortified dried

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whey by-product[5] (4%), a combination of dried whey product (4%) and sun-cured alfalfa meal (5%), and a combination of sardine condensed fish solubles (4%) plus sun-cured alfalfa meal (5%), as vitamin B_2 complex supplements to a "corn-soybean meal" basal ration for weanling pigs in drylot.

"Dried whey product" is defined by the American Feed Control Officials as "the dried product resulting from the partial removal of milk sugar from clean, sound whey to which no foreign substances have been added. This product shall contain at least 55 percent lactose (milk sugar)."

TABLE 1. COMPOSITION OF THE RATIONS FED,[1] (ALL PIGS SELF-FED IN DRYLOT, 1946 SUMMER), IN PERCENTAGES UNLESS OTHERWISE INDICATED

Ingredients	Lot and ration number					
	1	2	3	4	5	6
Ground yellow corn	59.5	60.0	56.0	60.0	56.0	57.5
Soybean meal, expeller	33.0	33.5	33.5	33.5	32.5	31.0
Alfalfa meal, sun-cured[2]	5.0	—	—	—	5.0	5.0
Dried whey product[3]	—	4.0	8.0	—	4.0	—
Fortified dried whey by-product[4]	—	—	—	4.0	—	—
Sardine fish solubles, condensed[5]	—	—	—	—	—	4.0
Minerals (H & K)[6]	2.0	2.0	2.0	2.0	2.0	2.0
Fortified vitamin A & D oil	0.5	0.5	0.5	0.5	0.5	0.5
Totals	100.0	100.0	100.0	100.0	100.0	100.0
Percent crude protein by analyses	20.6	20.6	21.0	21.0	20.9	21.5
Riboflavin, mg. per lb. by assay	1.3	1.9	1.8	1.8	1.7	1.8
Riboflavin, mg. per lb., estimate	1.6	1.6	1.7	1.9	1.6	1.6

[1] The following additions of crystalline riboflavin were made per 100 lbs. of ration: Lot 1, 34 mg.; Lot 2, 30 mg.; and Lot 6, 15 mg. All rations were estimated to contain at least 1.5 mg. of riboflavin per pound. Only the ration fed to Lot 1 contained less than this amount, according to the assay values.

[2] The alfalfa meal contained 15.8% crude protein, 31.5% crude fiber, 9.0 mg. carotene per pound and 3.8 mg. riboflavin per pound.

[3] The dried whey product contained 14.1% crude protein, 3.1% moisture, 59.9% lactose, 12.5% ash, 4.1 lactic acid and the following amounts of vitamins per pound, riboflavin 13.62 mg., niacin 4.86 mg., pantothenic acid (as d-ca-pantothenate) 22.7 mg., thiamin 6.58 mg., and biotin 0.23 mg.

[4] The fortified dried whey by-product contained 14.1% crude protein, 3.4% moisture, 59.7% lactose, 12.5% ash, 4.6% lactic acid, and the following amounts of vitamins per pound, riboflavin 27.64 mg., niacin 6.76 mg., pantothenic acid 19.98 mg. (as d-ca-pantothenate), thiamin 5.36 mg., and biotin 0.27 mg.

[5] The sardine condensed fish solubles contained 48.95% moisture, 31.0% crude protein, and 7.65 mg. riboflavin per pound.

[6] Krider *et al.* (1946).

"Dried whey by-product is any dried product, not otherwise defined, composed of whey constituents and containing less than 55% lactose (milk sugar)." Whenever the word fortified is used in the script it means fortified with "whey fermentation solubles (Ribolac)."

[5] Fortified dried whey by-product as used in this manuscript refers to dried whey by-product with whey fermentation solubles (Ribolac) added.

There were 72 weanling pigs allotted to the six lots. These spring pigs were raised to weaning age (56 days) in drylot and had been reared by sows that had been in drylot since before they were bred. The sows and pigs were fed rations that were considered to be nutritionally adequate during the lactation period. When each litter was 8 weeks old, the pigs were randomized into the six lots with consideration given to weight, condition, litter, sex, and thrift. Each pig was weighed off test on the weekly weigh-day at which its live weight was approximately 75 pounds. All pigs were self-fed, confined on concrete floors, bedded with shavings, and given water ad lib.

TABLE 2. RESULTS OF THE FIRST GROWING-FATTENING TEST (WEANING TO 75 LBS., 1946 SUMMER)

Items compared	Lot numbers and treatments					
	1	2	3	4	5	6
	5% alfalfa meal	4% dried whey product	8% dried whey product	4% fortified dried whey by-product	5% alfalfa meal +4% dried whey product	5% alfalfa meal +4% fish solubles
Number of pigs	12	12[1]	12	12	12[2]	12
Av. initial wt., lb.	30.0	30.4	30.0	30.4	31.4	30.7
Av. final wt., lb.	75.1	74.4	75.4	74.0	74.0	76.2
Av. daily gain, lb.	0.95[3]	0.77	0.90	0.82	0.82	0.93[3]
Av. daily feed, lb.	2.54	2.16	2.39	2.33	2.62	2.75
Feed eaten per 100 lb. gain, lb.	273	311	267	294	361	302
Coefficient of variation of av. daily gains, percent	12.1	25.9	13.6	19.9	29.6	14.5

[1] One pig removed from Lot 2.
[2] Two pigs removed from Lot 5.
[3] The average daily gains in Lots 1 and 6 were significantly more rapid than those in Lot 2 ($P \leq 0.05$).
The average daily gains in Lot 1 were significantly more rapid than those in Lot 4 ($P \leq 0.05$).
Other differences were not statistically significant.

The rations fed to the pigs are given in table 1 and the results are presented in table 2.

The results (table 2) supplemented with observations made during the test indicate that the most rapid gains were obtained by feeding 5% of sun-cured alfalfa meal (lot 1), although these gains did not differ significantly from those obtained by feeding either 8% dried whey product (lot 3) or the combination of 5% alfalfa meal plus 4% fish solubles (lot 6). In these three lots the gains were very uniform and the pigs were thrifty and sleek. Krider *et al.* (1947) have reported that weanling pigs in drylot gain slowly, show deficiency symptoms, and may die when fed a ration similar to those

above without the addition of the vitamin supplements.

One hundred pounds of dried whey product as fed to lot 3 was worth 64 pounds of alfalfa meal plus 3 pounds soybean meal and 60 pound of ground yellow corn (127 pounds total feed) in producing 100 pounds of gain when compared to lot 1 (5% alfalfa meal).

The addition of 4% sardine condensed fish solubles to a ration containing 5% sun-cured alfalfa meal did not result in either increased rate of gains or more economical gains than 5% sun-cured alfalfa meal as the only supplement.

During the experiment, it was apparent that pigs in all lots receiving dried whey products (lots 2, 3, 4, and 5) were affected with a diarrhea characterized by watery thin feces. Since the pigs in lot 3 receiving 8% of dried whey product gained almost as rapidly as the pigs in lot 1, it is believed that the scouring which occurred in this test was not necessarily harmful to the pigs. The relationship of lactose content of the diet to laxativeness was investigated in experiment 2.

The value of alfalfa meal as a vitamin B_2 complex supplement in a drylot ration containing only plant protein ingredients has again been demonstrated.

Experiment 2

The purpose was to study the relationship of lactose content of the diet

TABLE 3. COMPOSITION OF THE RATIONS FED IN EXPERIMENT 2, (1946 FALL), IN PERCENTAGES

Ingredients	Lot and ration number			
	2	2	3	4
Ground yellow corn	60.0	60.5	61.9	61.0
Soybean meal, expeller	33.5	34.6	33.0	33.3
Dried whey product[1]	4.0	—	—	—
Lactose	—	2.4	—	—
Dried whey by-product No. 1[2]	—	—	2.6	—
Dried whey by-product No. 2[3]	—	—	—	3.2
Minerals (H & K)	2.0	2.0	2.0	2.0
Fortified vitamin A and D oil	0.5	0.5	0.5	0.5
Totals	100.0	100.0	100.0	100.0
Crude protein, % of total ration	20.0	20.0	20.0	20.0
Lactose, % of total ration	2.4	2.4	1.08	1.7

[1] The dried whey product was identical to that fed in Experiment 1.

[2] The analysis of the dried whey by-product No. 1 was as follows: 4.3% moisture, 21.7% crude protein, 41.5% lactose, 19.7% ash, and 7.6% lactic acid.

[3] The analysis of the dried whey by-product No. 2 was as follows: 4.4% moisture, 17.6% crude protein, 54.3% lactose, 14.1% ash, and 4.1% lactic acid.

to the laxativeness of dried whey product when it was used as a vitamin supplement in drylot rations of young pigs.

Twenty-four young fall pigs that previously had been on pasture were used in the four lots. They were self-fed the rations given in table 3 and were confined on concrete floors.

In lots 1, 3 and 4 the dried whey products were fed to supply equivalent levels of dietary crude protein from each, hence permitting the lactose levels of the rations to vary. The ration fed to lot 1 was composed of the same ingredients as the ration fed to lot 2 in experiment 1.

In table 4 the results of experiment 2 are reported. The pigs were started on test December 19, 1946, and were self-fed.

TABLE 4. RESULTS OF VARYING THE LACTOSE CONTENT OF THE RATIONS (EXPERIMENT 2, 1946 FALL, 28 DAYS)

Items compared	Lot and ration number			
	1	2	3	4
Percent lactose in ration	2.4	2.4	1.08	1.7
Number of pigs	6	6	6	6
Av. initial weight, lbs.	52.7	53.3	53.2	53.2
Av. final weight, lbs.	93.0	86.0	87.7	91.5
Av. daily gain, lbs.	1.44[1]	1.17	1.23	1.37
Av. daily feed, lbs.	3.71	3.24	3.39	3.64
Feed eaten per 100 lbs. gain, lbs.	257	278	275	266

[1] Significantly more rapid av. daily gain in Lot 1 than in Lot 2 or 3 ($P \leqq 0.05$). Other differences were not statistically significant.

On December 27 (8 days after start of test) the feces of pigs in lots 1 and 2 were much thinner than the stools of pigs in lots 3 and 4. Four days later it was noted that feces of pigs in lots 3 and 4 did not appear to be nearly as thin and watery as those from pigs in lots 1 and 2. The stools in the latter two lots were quite thin. The pigs in lot 4 seemed to show a little sleeker haircoats than pigs in the other lots.

On January 7, 1947 (19 days after start of test) it was noted that in lots 1 and 2 there was much evidence of scouring, although some feces of normal consistency were being voided. In these lots there was more frequent occurrence of thin, watery, and mushy stools than in lots 3 and 4. The firmest and most normal feces were voided by pigs in lot 3. No pigs were scouring in this lot. Most feces of pigs in lot 4 were normal, but there were some "thin-mushy" feces.

On January 13, 1947, two of the authors observed that the thinnest feces were defecated by pigs in lot 2, and that the firmest feces were defecated by pigs in lot 4, with lots 3 and 1 intermediate in this respect.

At the close of the test, the pigs in lot 4 appeared to have the sleekest

haircoats and skins, while those in lot 2 were beginning to show considerable evidence of a probable vitamin deficiency. At the close of the test observations were made on each pig as it defecated. These observations are tabulated below. It was noted that there was less scouring in lot 1 at the close of the test than there had been at any previous time during the test.

	Number of pigs showing the following condition of feces		
	Normal	*Mushy*	*Thin and watery*
Lot 1	5	0	1
Lot 2	2	3	1
Lot 3	4	2	0
Lot 4	6	0	0

The scouring in pigs receiving 4% dried whey product (lot 1) was not harmful. These pigs gained significantly more rapidly than those in lot 2 indicating that the non-lactose constituents in the dried whey product were contributing to the nutrition of the pigs. As the test progressed, the pigs in lot 1 apparently adjusted themselves to this lactose level. This is in agreement with the observations made by Riggs and Beatty (1947) using rats as experimental animals. This was less evident in lot 2, since scouring in these pigs was observed throughout the test. In the latter part of the experiment, this may have been partly caused by the deficiencies of the ration fed. Feces of pigs receiving rations containing 1.08% and 1.7% lactose were nearly normal throughout the experiment, while feces of pigs receiving 2.4 lactose in their rations were thin and mushy most of the time.

Experiment 3

The objective was to study the value of two levels (2% and 4%) of fortified dried whey by-product in comparison with 10% dehydrated alfalfa meal for weanling pigs fed to 75 pounds in drylot. A fortified dried whey by-product containing 53.8% lactose was fed, which was similar to the product fed to lot 4 in experiment 2.

Forty weanling pigs were used that had been raised by sows fed nutritionally adequate rations in drylot since before they were bred. The same experimental procedure used in experiment 1 was followed. After all pigs in lots 2, 3 and 4 had reached 75 pounds the test was terminated even though some pigs in lot 1 (basal) had not attained this weight.

The rations fed are given in table 5 and the results are reported in table 6.

Either 2% or 4% fortified dried whey by-product supplied nutritional factors which significantly improved the deficient basal ration which con-

TABLE 5. COMPOSITION OF RATIONS FED IN EXPERIMENT 3, (DRYLOT, 1947 SUMMER), IN PERCENTAGES UNLESS OTHERWISE INDICATED

Ingredients	Lot and ration number			
	1	2	3	4
Ground yellow corn	66.5	65.0	63.0	59.0
Meat and bone scraps[1]	5.0	5.0	5.0	5.0
Soybean meal, expeller[2]	27.5	27.0	27.0	25.0
Dried whey by-product, fortified[3]	—	2.0	4.0	—
Alfalfa meal, dehydrated[4]	—	—	—	10.0
Ground limestone	0.5	0.5	0.5	0.5
Iodized salt	0.5	0.5	0.5	0.5
Manganese sulfate	0.01	0.01	0.01	0.01
Irradiated yeast premix[5]	0.02	0.02	0.02	0.02
Totals	100.0	100.0	100.0	100.0
Analyses and vitamin content of rations[6]				
Crude protein, %	20.5	19.5	20.3	20.5
Riboflavin, mg. per lb.	1.23	1.50	2.32	2.04
Niacin, mg. per lb.	11.08	10.90	10.90	11.44
Pantothenic acid, mg. per lb.	4.72	5.81	6.17	6.49

[1] The meat and bone scraps were Wilson's "Red W" Brand and were guaranteed to contain a minimum of 50% crude protein, 6% fat and maximum of 3% crude fiber.

[2] The expeller soybean meal was guaranteed to contain a minimum of 41% crude protein, 3.5%, fat 29% NFE and a maximum of 7% crude fiber.

[3] By analyses and assay, the fortified dried whey by-product contained 4.2% moisture, 17.7% crude protein, 14.6% ash, 53.8% lactose, 4.1% lactic acid and 26.0 mg. riboflavin per pound. Donated through the courtesy of Western Condensing Company, Appleton, Wisconsin.

[4] By assay and analyses the dehydrated alfalfa meal contained 17.9% crude protein, 21.6% crude fiber, 122.1 mg. carotene per lb., 17.3 mg. riboflavin per lb., 21.8 mg. niacin per lb. and 15.0 mg. pantothenic acid per pound.

[5] The premix was composed of 92.5% corn starch plus 7.5% irradiated yeast containing 12 million U.S.P. units of vitamin D per pound of yeast. Courtesy Dr. E. G. Wallis, Standard Brands Inc., New York, New York.

[6] Courtesy H. C. Schaefer, Ralston Purina Nutrition Research Laboratories, St. Louis, Missouri.

tained 5% of meat and bone scraps. Significantly more rapid average daily gains ($P \leqq 0.01$) were obtained in the supplemented lots (lots 2 and 3) than in the basal lot (lot 1).

The pigs fed either 2% or 4% of fortified dried whey by-product consumed 14% and 17% less feed, respectively, per 100 pounds live weight gain than pigs fed the basal ration. They also made average daily gains that were 30% and 32% more rapid. The pigs fed the fortified dried whey by-product gained slightly more rapidly and required slightly less feed per unit of gain than those receiving 10% dehydrated alfalfa meal as a B_2-complex vitamin supplement.

The high feed replacement values of the fortified dried whey by-product and the dehydrated alfalfa meal when compared to the inadequate basal

ration emphasize the importance of vitamin B_2-complex supplements in drylot rations for weanling pigs.

In this trial, 100 pounds of fortified dried whey by-product fed as 2% of the ration was equal in value to 613 pounds ground corn, 39.7 pounds meat scraps, 247.6 pounds soybean meal and 9.5 pounds minerals, without considering the advantage of the more rapid gains (lot 1 versus lot 2). When fed as 4% of the ration, 100 pounds of fortified dried whey by-product was equal to 433 pounds ground corn, 25.6 pounds meat scraps, 156.2 pounds soybean meal and 5.8 pounds minerals (lot 1 versus lot 3).

TABLE 6. RESULTS OF EXPERIMENT 3 (WEANING TO 75 LBS., DRYLOT, 1947 SUMMER)

Items compared	Lot numbers and treatments			
	1	2	3	4
	Basal	Basal+2% fortified dried whey by-product	Basal+4% fortified dried whey by-product	Basal+10% dehydrated alfalfa meal
Number of pigs	10	10[1]	10	10[1]
Av. initial weight, lbs.	33.6	34.2	33.6	33.7
Av. final weight, lbs.	69.3	74.8	74.6	74.8
Av. daily gain, lbs.	0.69	0.90[2]	0.91[2]	9.81
Av. daily feed, lbs.	2.19	2.54	2.50	2.55
Feed eaten per 100 lbs. gain, lbs.	365	314	302	334
Coefficient of variation of av. daily gains, percent	43.0	28.2	26.9	24.0

[1] One pig removed from test and was not included in summary.
[2] Av. daily gain highly significant over Lot 1 ($P \leq 0.01$). Other differences were not statistically significant.

Each 100 pounds of dehydrated alfalfa meal was equal in value to 136.5 pounds ground corn, 4.5 pounds meat scraps, 50.6 pounds soybean meal and 1.2 pounds minerals (lot 1 versus lot 4).

When 2% fortified dried whey by-product was compared with 10% dehydrated alfalfa meal, 100 pounds of fortified dried whey by-product was equal in value to 530 pounds dehydrated alfalfa meal, 15.9 pounds meat scraps and 3.2 pounds minerals minus 111 pounds ground corn and 20.6 pounds soybean meal.

Summary and Conclusions

Three experiments are reported in which 136 young pigs were self-fed in drylot. The value of 5% sun-cured alfalfa meal, 4% dried whey product, 8% dried whey product and 4% fortified dried whey by-product as water-soluble vitamin supplements to a ration composed largely of corn and soy-

bean meal is indicated. The addition of 4 % sardine condensed fish solubles or 4% dried whey product to a ration containing 5% sun-cured alfalfa meal did not improve the growth rate of weanling pigs. The above levels of whey products induced a somewhat laxative condition in the pigs.

In experiment 2, lactose was found to be a constituent of dried whey which contributed to the laxative condition. In all tests it was observed that the laxativeness was not detrimental to the rate or economy of gains. Pigs fed rations containing 1.1% or 1.7% lactose for 28 days scoured less than those fed rations containing 2.4% lactose. The non-lactose constituents, probably the B_2 vitamins, in the dried whey product (fed as 4% of the ration) contributed to the nutrition of young pigs and produced daily gains that were significantly more rapid than those of pigs fed a ration containing 2.4% of pure lactose.

The results in experiments 1 and 2 suggest that in this type of ration, lactose is laxative in nature when fed at relatively low levels. However, the growth promoting ability of the whey products was not retarded by these relatively low lactose levels in the rations.

The addition of either 2% or 4% fortified dried whey by-product supplied essential nutritional factors which significantly improved growth of weanling pigs receiving a basal ration containing 5% meat and bone scraps. The pigs fed 2% or 4% fortified dried whey by-product ate 14% and 17% less feed, respectively, per 100 pounds live weight gain than similar pigs fed the unsupplemented basal ration.

The value of high-quality alfalfa meal, either sun-cured or dehydrated, as a B_2-complex supplement is again indicated.

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RESPONSE OF WEANLING PIGS TO VARIOUS LEVELS OF RIBOFLAVIN[1]

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FOR weanling pigs, the practical minimum level of riboflavin appears to be approximately 1.4 mg. per pound of ration consumed in the drylot experiments herein reported.

Hughes (1940) reported a minimum requirement of between 1 and 3 milligrams of riboflavin per 100 pounds body weight per day. This would be equivalent to 0.25 to 0.75 mg. per pound of ration consumed if the pig ate 4 pounds of feed per 100 pounds of body weight daily. The National Research Council Committee on Animal Nutrition (1944) recommends 3.8 milligrams of riboflavin daily per day for a 100-pound pig, or .76 milligram per pound of ration. Van Poucke and Krider (1946) reported more rapid and more efficient gains of weanling pigs fed 1.5 milligrams of riboflavin per pound of purified diet than when 0.5 or 0.75 mg. was fed.

Procedure

Experiment 1. Purified rations fed (1945 Summer)

Four groups of six pigs averaging 30 pounds were started on experiment June 11, 1945 and were fed in drylot for 11 weeks on purified rations containing 0.0, 0.5, 0.75, and 1.50 mg. of riboflavin per pound of diet. The pigs fed the latter three rations were full-fed individually twice daily, while the basal group was full-fed as a group. All pigs were fed the basal ration for 10 days preceding the experimental period, and had been in drylot since birth.

The basal ration was composed of:

Corn starch	61.0%
Labco vitamin-free casein	25.0%
Cerelose	10.0%
Salt mixture (Hughes, 1942)	4.0%
Thiamin	1.0 mg. per lb. of ration
Niacin	4.0 mg. per lb. of ration
Calcium pantothenate	3.0 mg. per lb. of ration
Pyridoxine	2.0 mg. per lb. of ration
Choline chloride	475.0 mg. per lb. of ration
Inositol[4]	454.0 mg. per lb. of ration

[1] This investigation was supported by the donation of funds and products to the University of Illinois by Hoffmann-LaRoche, Inc., Nutley, New Jersey, and by Commercial Solvents Corporation, Terre Haute, Indiana.

[2] Present address, Western Condensing Co., Appleton, Wisconsin.
[3] Animal Science Department, Urbana, Illinois.

[4] Supplied by the A. E. Staley Manufacturing Company, Decatur, Illinois.

Each pig received 10 cc. of fortified cod-liver oil (Nopco XX) once per week. This product was guaranteed to contain 2000 I.U. of vitamin A and 400 U.S.P. units of vitamin D per gram.

Experiment 2. Practical rations fed (1947 Fall)

Fifty head of weanling fall pigs that had been raised in drylot were group-fed to determine the value of riboflavin supplementation of a good basal ration which contained 1.18 milligrams of riboflavin per pound. This value is an average of the assays done at two laboratories on the composite samples of the basal ration.[5] Since the microbiological assay method is subject to considerable error when used on feeds or mixed rations, it is believed that the average riboflavin value is more representative than the lowest or highest value obtained. Based upon the average riboflavin content of the feeds used, the basal ration was estimated to contain 1.11 mg. per pound. The pigs averaged 38 pounds initially and were self-fed to a final weight of 100 pounds. Each pig started on test when 56 days old and was removed on the weekly weight day that it weighed approximately 100 pounds.

The basal ration contained 46% ground yellow corn, 24% hulled oats, 21% expeller soybean meal, 5% meat scraps (55% crude protein), 3% high-quality dehydrated alfalfa meal, 0.5% ground limestone and 0.5% iodized salt. One-tenth pound of manganese sulfate was added per 1000 pounds of ration and irradiated yeast[6] was added to supply 180 U.S.P. units of vitamin D_2 per pound of ration. The basal ration contained 20.9% crude protein, 3.8% fiber, 0.7% calcium, 0.6% phosphorus, 48 p.p.m. of manganese, 10 7 mg. niacin, 4.7 mg. pantothenic acid and 576 mg. choline per pound.

The lots were treated as follows:

Lot 1. Basal ration.

Lot 2. Basal ration plus 0.25 mg. riboflavin per pound of ration from dried fermentation solubles.

Lot 3. Basal ration plus 0.50 mg. riboflavin per pound of ration from dried fermentation solubles.

Lot 4. Basal ration plus 0.50 mg. crystalline riboflavin per pound of ration.

Lot 5. Basal ration plus 1.0 mg. riboflavin per pound of ration from dried fermentation solubles.

The dried fermentation solubles by assay contained 3630 milligrams of riboflavin per pound. It was premixed with soybean meal before it was added to the ration.

One gram of crystalline riboflavin was premixed with 100 grams of corn starch, then added to 10 pounds of soybean meal. This premix was then added to supply 0.5 mg. riboflavin per pound of ration for lot 4.

[5] We are grateful to Dr. B. C. Johnson, Animal Nutrition Division, University of Illinois and to H. C. Schaefer Research Laboratories, Ralston-Purina Co., St. Louis, Mo., for these assays.

[6] Supplied by Standard Brands, New York, N. Y.

Results and Discussion

Experiment 1

The results of feeding the various levels of riboflavin to weanling pigs receiving the purified ration after a 10-day depletion period are given in table 1.

Pigs fed 0.75 mg. riboflavin required an average of 18% more feed to produce a pound of gain than those receiving 1.50 mg. of riboflavin per pound of ration. The most thrifty group at the close of the test was the one receiving the highest level of riboflavin. These results indicate that riboflavin is associated with the utilization of feed for growth.

Post mortem examination of the basal pigs showed extremely thickened skin; edematous areas beneath the skin; edematous fluid infiltrated between

TABLE 1. RESPONSE OF "DEPLETED" WEANLING PIGS TO RIBOFLAVIN SUPPLEMENTATION (77 DAYS, DRYLOT, 1945 SUMMER)

Items compared	Group number			
	1[1]	2	3	4
Riboflavin, mg. per lb. of ration	0.0	0.50	0.75	1.50
Number of pigs	7	6	6	6
Initial weight per pig, lbs.	30	32	31	32
Final weight per pig, lbs.	50	79	76	91
Av. daily gain, lbs.	0.18	0.61	0.58	0.77
Av. feed consumed per 100 lbs. body weight daily, lbs.	1.95	2.60	2.44	2.63
Av. riboflavin consumed per 100 lbs. body weight daily, mgs.	0.00	1.30	1.83	3.95
Feed eaten per pound gain, lbs.	4.50	2.05[2]	2.26	1.92

[1] 7 pigs started, 5 finished, group-fed.

[2] Only 5 pigs used in this average since one pig failed to gain.

muscles, under muscular sheaths, and in the abdominal and thoracic cavities; enlarged spleens; anemia; and light gray discoloration of the kidneys. No external deficiency symptoms were noted in pigs receiving various levels of riboflavin while those fed the basal ration showed symptoms described by Hughes (1940).

At the close of the test, liver and muscle samples were taken from the basal pigs and were assayed for riboflavin.[7] One pig fed 1.5 mg. riboflavin per pound of ration was also sacrificed. The liver and muscle from this pig (lot 4) contained 100.1 and 7.2 micrograms respectively of riboflavin per gram of dry matter. Liver and muscle samples from the basal pigs averaged 36.6 and 4.7 micrograms of riboflavin per gram of dry matter, respectively.

The average daily gains of the pigs fed riboflavin were highly significant

[7] We are grateful to Dr. B. C. Johnson, Animal Nutrition Division, University of Illinois, for these assays.

$P<0.01$) over those made by the basal group (Snedecor, 1940). The odds were 17 to 1 that the more rapid gains of pigs in lot 4 over lot 3 were not due to chance alone. The same odds favored the higher level of riboflavin (1.5 mg. per pound of ration) in the statistical analysis of feed required per pound of gain.

Experiment 2

The results of the test in which practical rations were fed are given in table 2.

From these results, it appears that 1.43 mg. of riboflavin is more nearly the practical minimum than 1.18 mg. per pound of ration which was the amount contained in the basal ration. The additions of riboflavin induced more rapid and more uniform gains and without exception produced more

TABLE 2. RESPONSE OF PIGS FED GOOD RATION PLUS RIBOFLAVIN SUPPLEMENTATION (10 PIGS PER LOT FED FROM 38 TO 100 LBS., DRYLOT, 1947 FALL)

Lot No. and riboflavin content of ration		Av. daily gain	Coefficient of variation of daily gains	Av. daily feed	Feed per 100 lbs. gain
	mg. per lb.	*lbs.*	*percent*	*lbs.*	*lbs.*
Lot 1	1.18	.81	31	3.1	394
Lot 2	1.43	.93	13	3.1	338
Lot 3	1.68	.90	20	3.2	364
Lot 4	1.68	.93	17	3.2	357
Lot 5	2.18	.86	23	2.9	337

efficient gains as measured by feed per 100 pounds gain. The odds are 16 to 1 that the improved growth rates of pigs in the supplemented lots were due to factors other than chance. Riboflavin from dried fermentation solubles induced the same response as the addition of the same level of crystalline riboflavin.

No marked deficiency symptoms were noted in the basal group, although the haircoats of the pigs were not as smooth and sleek as the haircoats of pigs fed the riboflavin supplements.

Conclusions

Under the experimental conditions imposed, 1.4 mg. of riboflavin per pound of ration appears to be the practical minimum level for weanling pigs fed in drylot.

No riboflavin deficiency symptoms except slow growth rate were noted when pigs received purified rations containing 0.5 or 0.75 mg. of riboflavin per pound of ration.

Feed efficiency was improved 18% when the riboflavin level was increased from 0.75 to 1.50 mg. per pound of purified ration for "depleted" weanling pigs. Feed efficiency was improved 17% when the riboflavin level of a good practical ration was increased from 1.18 to 1.43 mg. per pound of ration for weanling pigs group-fed in drylot.

In a practical ration for weanling pigs fed in drylot, the addition of crystalline riboflavin produced the same response as the addition of an equal amount of riboflavin from dried fermentation solubles.

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DRIED MOLASSES, POTATO, OR CORN DISTILLERS' SOLUBLES AS PART OF A RATION FOR FATTENING PIGS IN DRYLOT[1]

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IN studies at the Illinois Station, Fairbanks *et al.* (1943) and Krider *et al.* (1944) reported that a basal ration composed of commonly used ingredients supplemented with dried corn distillers' solubles, corn distillers' dried grains with solubles, or alfalfa meal was effective for growing-fattening swine. Bohstedt *et al.* (1943) showed that dried distillers' solubles have a "favorable supplementary effect" when fed to growing-fattening swine in drylot. Distillers' dried solubles used as a vitamin source effectively supplemented drylot rations containing either a small quantity of animal protein or an all-vegetable protein (Snyold, 1945). Fairbanks *et al.* (1945) demonstrated the value of alfalfa meal as a source of water-soluble factors needed to supplement the basal ration for growing-fattening pigs fed in drylot from birth. Ellis and Zeller (1947), after feeding dried distillers' solubles from corn, potatoes and molasses, reported that all groups made efficient use of the feed consumed. The least efficient in terms of gains and feed utilization, was the group fed 40 percent dried molasses solubles, and the most efficient, the group fed dried potato solubles.

This paper reports a trial of dried distillers' solubles derived from corn, potatoes, or molasses[2] as part of a ration for fattening pigs in drylot. The purposes were: 1. To compare the feeding values of the three distillers' solubles as supplements to a basal ration; 2. To compare the feeding values of two different levels of each distillers' soluble as a supplement to a basal ration; 3. To compare a basal ration and molasses grain solubles fed free-choice; 4. To determine the effect of substituting molasses grain solubles for alfalfa leaf meal in a ration.

Materials and Methods

Seventy-two purebred Duroc Jersey and Berkshire pigs were used through out the trial. They were divided equally into nine pens of eight each according to breed, sex, and weight, and were drylot fed from weaning. The trial was run during the summer of 1947.

Two basal rations were used during the trial for eight pens. The first ration, containing approximately 20 percent crude protein, was fed until

[1] Journal Series Paper of the New Jersey Agricultural Experiment Station, Rutgers University, Department of Animal Husbandry, New Brunswick, N. J.

[2] The solubles were kindly furnished by the Publicker Industries, Inc., Philadelphia, Pa., through the courtesy of Mr. V. G. Aubry.

the fattening pigs in each group averaged 100 pounds in liveweight; the second ration, the crude protein content of which was reduced to approximately 15 percent, was fed from then on. To the basal rations of groups 1, 3, and 5, 12 percent dried molasses distillers' solubles, dried potato distillers' solubles, and dried corn distillers' solubles, respectively, were added. Groups 2, 4, and 6 received 9 percent dried molasses distillers' solubles, dried potato distillers' solubles, and dried corn distillers' solubles, respectively, as supplements to the basal rations. The pigs in group 7 were fed the

TABLE 1. COMPOSITION OF BASAL RATIONS

Ingredient	Basal ration 1	Basal ration 2	Basal ration 3	Basal ration 4
	%	%	%	%
Ground yellow corn	67.0	78.5	65.0	76.0
Tankage, 60% protein	15.0	7.5	13.0	5.0
Soybean meal, 41% protein	8.0	4.0	8.0	5.0
Alfalfa meal, 17% protein	8.0	8.0	—	—
Molasses grain solubles	—	—	12.0	12.0
Minerals*	2.0	2.0	2.0	2.0

* Minerals 2 parts each lime and bonemeal, 1 part salt.

basal rations as a check group. Group 8 was fed the basal rations and dried molasses distillers' solubles free-choice.

Group 9 was likewise fed two basal rations: one, containing approximately 20 percent crude protein, until the pigs averaged 100 pounds in liveweight; and the other, containing 15 percent crude protein, thereafter. In these rations 12 percent dried molasses distillers' solubles were substituted for alfalfa meal.

All groups were self-fed throughout the trial. Initial and final weights were determined for each pig on trial. Weekly group weights were obtained to determine the progress of each group. All ingredients used in the rations are shown in table 1.

Results and Discussion

The results of this experiment, including gain in weight and feed consumption for each group of pigs, are shown in table 2.

Molasses solubles

Group 1, fed 12 percent molasses distillers' solubles as a supplement to a basal ration, consumed 383.6 pounds of feed for each 100 pounds gain in liveweight. The average daily gain was 1.41 pounds. Group 2, fed 9 percent

TABLE 2. FEEDING RESULTS OF DIFFERENT LEVELS OF DRIED MOLASSES, POTATO, OR CORN DISTILLERS' SOLUBLES IN THE RATION OF 72 FATTENING PIGS. (NUMBER OF PIGS; 8; DAYS ON TRIAL, 82; ALL FIGURES, POUNDS)

	Group 1, basal plus 12 percent molasses solubles	Group 2, basal plus 9 percent molasses solubles	Group 3, basal plus 12 percent potato solubles	Group 4, basal plus 9 percent potato solubles	Group 5, basal plus 12 percent corn solubles	Group 6, basal plus 9 percent corn solubles	Group 7, basal (control)	Group 8, basal & molasses, solubles, free-choice	Group 9, no alfalfa meal
Total initial weight	397	396	404	407	400	403	403	401	419
Total final weight	1322	1366	1337	1371	1315	1355	1409	1385	1292
Total gain in weight	925	970	933	964	915	952	1006	984	873
Average daily gain	1.41	1.48	1.42	1.47	1.39	1.45	1.53	1.50	1.33
Total feed consumed	3548.0	3774.1	3528.0	3737.9	3388.0	3510.9	3765.0	3675.0	3410.0
Feed consumed for 100-lb. gain in weight	383.6	389.1	378.1	387.8	370.3	368.8	374.3	373.5	390.6

of the molasses distillers' solubles, gained 1.48 pounds daily using 389.1 pounds of feed for each 100 pounds gain in liveweight. This comparison shows that the group fed 9 percent molasses distillers' solubles had a slightly higher average daily gain with higher feed consumption.

Potato solubles

Group 3, fed 12 percent dried potato distillers' solubles, gained 1.42 pounds daily, using 378.1 pounds of feed for each 100 pounds of gain in liveweight. The fourth group, receiving 9 percent of these solubles, showed a slightly higher average daily gain of 1.47 pounds, but required approximately 9.7 pounds more feed for each 100 pounds of gain in liveweight.

Dried corn solubles

The fifth group of hogs, fed 12 percent of dried corn distillers' solubles, consumed 370.3 pounds of feed for each 100 pounds of gain in liveweight and showed an average daily gain of 1.39 pounds. The sixth group, fed 9 percent of these solubles, showed greater efficiency in average daily gain (1.45 pounds) and feed consumption (368.8 pounds of feed for each 100 pounds of gain in weight).

Control

Group 7, used as the control group, showed the highest average daily gain of 1.53 pounds and a feed consumption of 374.3 pounds for each 100 pounds of gain in liveweight.

Free-choice

Feeding dried molasses distillers' solubles and either ration 1 or 2 free-choice to group 8 resulted in too little consumption of solubles to warrant computation as part of the feed intake. In this group, average daily gain of 1.50 pounds with a feed consumption of 373.5 pounds for each 100 pounds gain in liveweight was comparable to that of the control.

Alfalfa leaf meal

Group 9, fed rations 3 and 4 in which 12 percent dried molasses distillers' solubles were substituted for alfalfa leaf meal, consumed the most feed per 100 pound gain in liveweight and showed the lowest average daily gain of all groups.

On the basis of feed consumed, groups 1 to 7, fed basal rations alone or fed dried molasses, potato, or corn distillers' solubles at the two levels as supplements to basal rations, showed no extreme differences. The range for feed consumed for each 100 pounds of gain in liveweight was 368.8 pounds

for the 9 percent dried corn distillers' solubles to 389.1 pounds for the 9 percent dried molasses distillers' solubles. The average daily gains for these seven groups ranged from 1.39 pounds for the 12 percent dried corn distillers' solubles group to 1.53 pounds for the control group.

Of the groups fed distillers' solubles, those receiving the 9 percent level of corn solubles showed the most efficient results in feed consumed; that receiving molasses solubles at the 9 percent level showed the highest rate of gain (1.48 pounds) and the least efficient feed consumption; and that fed 12 percent corn solubles showed the lowest rate of gain (1.39 pounds). The results on comparative efficiency of feed consumption are in partial agreement with the work of Ellis and Zeller (1947).

The results with group 8, which received the dried molasses distillers' solubles free-choice with the basal ration, have no significance. Failure of the pigs to eat much of the solubles was probably due to the odor and lower palatability in comparison with the basal ration.

Substitution of 12 percent dried molasses distillers' solubles for alfalfa leaf meal in the ration, besides decreasing efficiency of feed consumption and daily gains, produced pigs that were abnormal in appearance, particularly in the legs and feet, and generally unthrifty. The control group had no indications of these symptoms and consumed 3.9 percent less feed and showed 13 percent higher average daily gains. Fairbanks *et al.* (1945), in a similar trial, concluded that alfalfa meal is more effective and economical than distillers' by-products alone in a basal ration for growing-fattening pigs, It is quite apparent that alfalfa leaf meal in a ration must contain factors that are lacking in the dried molasses solubles and that make it a more complete ration nutritionally.

Summary and Conclusions

A basal ration containing ground yellow corn, tankage, soybean oil meal, alfalfa meal, and minerals was supplemented with 12 percent or 9 percent of dried molasses, corn, or potato distillers' solubles and fed to purebred Duroc Jersey and Berkshire pigs for 82 days.

Supplementing the basal ration with 9 percent of the distillers' solubles gave an average daily gain of 1.45 to 1.48 pounds, compared to 1.39 to 1.42 pounds for the 12 percent groups.

The feed consumption for each 100 pounds of gain was less for both the 12 percent dried molasses and potato distillers' solubles groups than for the 9 percent groups. The 9 percent dried corn soluble group required less feed than its corresponding 12 percent group.

The higher average gains at the 9 percent levels, even though more feed is required, may be due to a more palatable ration. Substantiating the prob-

able unpalatability of the 12 percent levels of distillers' solubles is the fact that one group fed a basal ration and dried molasses solubles free-choice consumed no more than 5 pounds of solubles during the entire trial.

The control group, fed a basal ration containing alfalfa meal, responded most efficiently in both average daily gains and feed intake. The pigs in one group fed a basal ration in which the alfalfa leaf meal was replaced with dried molasses distillers' solubles were unthrifty in appearance and abnormal in development of legs and feet. These conditions may have been due to inadequacy of the diet in certain nutritional factors required by growing-fattening pigs in drylot from birth.

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THE EFFECT OF PLANE OF NUTRITION ON THE ECONOMY OF PRODUCTION AND CARCASS QUALITY OF SWINE[1]

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IT is generally recognized that each individual reaches its ultimate attainment as the result of the two forces, heredity and environment. The inter-relationship of heredity and environment and their respective influences on the individual's development are of interest and importance to both the student of breeding and the student of nutrition. There are various methods of approaching the problem of appraising their respective influences. One method is by subjecting similar genetic materials to different environmental conditions and another is by subjecting different genetic materials to similar environmental treatments. Both methods have been used in this study.

Dickerson (1947) from a study of data from the Iowa Swine Breeding Project reported a correlation of 0.60 or more between rate of gain to 225 pounds and degree of fatness and a negative correlation of $-.6$ to $-.7$ between rapid fat deposition and feed requirements. As a result of his study Dickerson makes this statement, "Rapid fat deposition and low feed requirements tended to be caused by the same genes, ..."

Blunn and Baker (1947) reported a correlation of 0.29 between rate of gain and depth of backfat. Their reported correlation is only about half of that found by Dickerson. They were working with the Duroc breed only. Dickerson's study included Poland China, Landrace and Landrace-Poland China crossbreds; the Poland China numbers were, however, in predominance. As a result of the differences in results between the two experiments Blunn and Baker suggest the results may indicate a breed difference in the relationship between fatness and rate of gain.

Mansfield and Trehane (1935) reported on an experiment in which one-half of the pigs were full-fed and the other half were fed on a restricted diet. The pigs on the restricted diet consumed less feed per unit of gain and yielded a higher percentage of carcasses that graded A and B. McMeekan and Hammond (1940) reported on a rather unique experiment; the pigs were divided into four groups and fed as follows.

[1] Paper No. 2414, Scientific Journal Series of the Minnesota Agricultural Experiment Station. The data from the swine breeding project were obtained from a project that is cooperative with the Regional Swine Breeding Laboratory, Ames, Iowa, Bureau of Animal Industry, U. S. Department of Agriculture. The calculations of data were made possible by a Grant in Aid of Research for the Graduate School of the University of Minnesota.

Lot	*Designation*	*First period*	*Second period*
1	HH	full-fed	full-fed
2	HL	full-fed	restricted ration
3	LH	restricted ration	full-fed
4	LL	restricted ration	restricted ration

They found that the different methods of feeding had an important effect on the type of carcass produced. They reported that rapid early growth and slow later growth intensifies the early developing tissues and inhibits the later developing tissue; muscle and bone are regarded as early developing tissue and fat as a late developing tissue.

Lot 2, HL had the proportionately best developed muscle and a minimum of fat. Lot 3, LH, on the other hand, had proportionately the least amount of lean and the most fat. Lot 4, LL, had a minimum of fat but the lean was not well developed.

Verges (1939) reported on an experiment with lambs designed similarly to McMeekan and Hammond's experiment with swine. He found that the lambs fed the HH rations produced the superior light lamb carcasses.

McMeekan (1940) in a study of muscle development found that growth occurred first by an increase in the number of cells and later by an increase in cell size. The animal that is full-fed early in life will therefore develop the maximum number of cells. The result is that two animals of different ages may have the same sized eye of loin but the muscle fibers of the younger animal will be smaller.

Callow and Kitchen (1931) showed that as the growth rate increased the average iodine number of the back-fat decreased indicating a firmer fat. Callow (1935) explained the association of rapid growth and firm fat to the fact that a fast gaining pig builds most of his fat from carbohydrates which produce a firm fat, whereas the slow gaining pig builds his fat from the fats and oils in the feeds which tend to produce a soft fat that is high in unsaturated fatty acids.

Object of the Experiment

The object of the present study was to obtain further information concerning the effect of different levels of feed intake on economy of production and carcass quality in swine.

Design of the Experiment

Eighty pigs belonging to the Poland China, Duroc, and Chester White breeds were assigned to four lots and fed as indicated: Lot 1, self-fed the entire feeding period; Lot 2, self-fed until the pigs weighed 125 pounds, then the feed was restricted to 3 percent of body weight; Lot 3, the feed was

restricted to 3 percent of body weight until the pigs weighed 125 pounds, then it was self-fed to the finish; Lot 4, the feed was restricted to 3 percent of body weight for the entire feeding period.

The pigs were weighed weekly and the feed adjusted accordingly. Each group was fed as a lot on pasture until the pasture season was over. Early in the experiment three pigs were removed from both lots 1 and 2 because of death or lack of thrift that apparently was not related to the experiment; hence the numbers were reduced to 17, 17, 20 and 20 pigs in each lot respectively.

The rations fed were.

	Corn, lbs.	*Ground oats, lbs.*	*Tankage, lbs.*	*Soybean, meal, lbs.*	*Alfalfa meal, lbs.*	*Salt and limestone, lbs.*
First 28 days	70	10	10	10		1
Second 28 days	80		10	10		1
Third 28 days and balance of pasture period	85		7.5	7.5		1
Dry lot period	80		6.0	6.0	8	1

Results and Discussion

The feed-lot data are given in table 1.

Each hog was slaughtered as close as possible to a live weight of 215 pounds, but it was impossible to slaughter more than one day a week; hence there was some variance in slaughter weight. The carcass data are presented in table 2.

Lot 1, the full-fed group, yielded the fattest carcasses, and lot 4, the restricted group, yielded the leanest carcasses. Lots 2 and 3 yielded carcasses with essentially the same degrees of fatness. The data on loss in skinning hams is in keeping with the data on fat cuts. As might be expected the data on percent of five primal cuts is in reverse to that of the percent of fat cuts; lot 4 yielded the highest percent, lot 1 the lowest with lots 2 and 3 falling in between with essentially the same yield. If a high percentage of the five primal cuts and a low percentage of fat cuts were the only prerequisites to a superior carcass then lot 4 would excel in carcass quality. Firmness, fineness of texture and flavor are other attributes of a superior carcass. Detailed data were not gathered on these characteristics, but the observations were that the meat of lot 4 lacked in firmness and was somewhat coarser in texture than that of lot 1.

TABLE 1. FEED LOT DATA ON PIGS FED AT DIFFERENT LEVELS OF FOOD INTAKE

Item compared	Lot			
	1	2	3	4
Feeding practice 1st period	full-fed	full-fed	restricted	restricted
Feeding practice 2nd period	full-fed	restricted	full-fed	restricted
Average initial weight per pig, lbs.	42.25	41.75	42.85	51.80
Average daily rate of gain, 1st period	1.22	1.21	.72	.72
Average daily rate of gain, 2nd period	1.61	1.17	2.16	1.24
Total	1.40	1.19	1.11	0.92
Average weight at close of experiment, lbs.	217	214	215	216
Average age at completion of trial	206	219	230	266
Feed per 100 pounds gain, initial weight to 125 pounds	339	337	334	338
Feed per 100 pounds gain, 125 pound weight to final weight	423	422	444	391
Feed per 100 pounds gain, for entire period[1]	383	381	391	365

[1] In order to adjust for the change from pasture to dry lot the pigs were charged the same amount of feed from pasture as alfalfa supplied in dry lot.

TABLE 2. CARCASS DATA ON HOGS FED AT DIFFERENT LEVELS OF FEED INTAKE

Item compared	Lot			
	1	2	3	4
Live slaughter weight, lbs.	216	215	215	216
Dressing percent	71	69	68	68
Cold carcass weight, lbs.	153	148	147	147
Backfat thickness inches average three three measurements	1.69	1.45	1.52	1.37
Length of carcass, inches	29.1	29.1	28.8	29.1
Five primal cuts, percent[1]	69.47	70.43	69.76	72.11
Ham, skin on	21.63	22.30	22.25	23.04
Picnic	9.05	9.21	9.19	9.61
Boston Butt	6.68	6.88	6.95	7.33
Loins	14.64	15.26	14.91	16.22
Bellies	17.46	16.78	16.45	15.92
Fat cuts, percent[1]	20.23	18.36	18.18	16.31
Fat backs	9.78	8.61	8.72	7.66
Plates	3.35	2.96	3.12	2.52
Leaf lard	3.18	3.35	2.90	2.91
Jowls	3.92	3.44	3.45	3.22
Total trimmings[2]	1.030	11.21	12.06	11.58
Loss in skinning hams, percent cold carcass weight[3]	2.15	1.87	1.98	1.65

[1] Based on cold carcass weight.

[2] Arrived at by deduction.

[3] The hams were skinned so the same thickness of fat was left on each ham.

The data in table 1 show that the gross feed per 100 pounds of gain was about the same for the four lots with some advantage for lot 4 even though lot 1 finished at a much younger age and lot 4 at a much older age. Differences in rates of gain result in differences in the gross amounts of nutrients required for maintenance. Maintenance requirements were calculated according to Brody (1945). When maintenance requirements are subtracted from the total nutrients supplied it leaves the nutrients available for gain in weight. The results of these calculations are presented in table 3.

TABLE 3. TOTAL T.D.N. SUPPLIED AND T.D.N. AVAILABLE FOR GROWTH OF HOGS FED AT DIFFERENT LEVELS OF FEED INTAKE

Item compared	Lot			
	1	2	3	4
Average total T.D.N. per lb. of gain	3.13	3.14	3.18	2.98
T.D.N. available over and above maintenance per lb. of gain				
1st period	1.93	1.90	1.34	1.34
2nd period	2.32	1.97	2.68	1.85
Both periods	2.13	1.94	2.05	1.61

The least amount of T.D.N. was required per pound of gain for the hogs in lot 4 which lot also yielded the leanest carcasses. Lot 1 which yielded the fattest carcasses required the largest amount of T.D.N. and lots 2 and 3 were intermediate in both respects. These data are in keeping with the known facts that lean meat contains a higher percentage of moisture than fat and that protein contains less T.D.N. than fat.

The natural deduction from the above is that it requires less feed to produce a lean animal than a fat one; therefore, selection based on economy of feed per unit of gain should be inducive to the development of lean animals.

This deduction, however, is not readily reconciled with Dickerson's (1947) finding that "Rapid fat deposition and low feed requirements tended to be caused by the same genes . . . " This association he attributed to a combination of less activity and a larger appetite. In comparing the results from the two studies it needs to be kept in mind that Dickerson's results were obtained from data wherein the attempt was to maintain a uniform environment and heredity supplied the variable; in this experiment the attempt was to maintain a constant heredity and make environment the variable.

By using some data from the Minnesota Swine Breeding Project, it is

possible to approach the problem from a still different angle. These data are presented in table 4; they are from the different groups of crossbreds and the data pertain to breeding, rate of gain, carcass qualities, feed per 100 pounds gain, total T.D.N. per pound of gain and T.D.N. available per pound of gain. All of the groups were full-fed essentially the same rations and provided an environment similar to that of the hogs in lot 1, tables 1, 2 and 3. With the exception of the M-2-M pigs the groups listed in table 4 made both decidedly more rapid gains and more efficient gains than the pigs in

TABLE 4. FEED LOT PERFORMANCE, CARCASS QUALITIES AND T.D.N. REQUIREMENTS OF CROSSBRED SWINE FROM THE MINNESOTA SWINE BREEDING PROJECT

Items compared	Breeding			
	V-B.S.-M.L.	N-2M	2-V	2-2-1
Av. daily rate of gain	1.74	1.44	1.60	1.93
Feed, lbs. per 100 lbs. gain, 8 per cent added for pasture	306	379	305	329
Av. backfat thickness, inches	1.45	1.40	1.29	1.56
Five primal cuts, percent cold carcass weight	71.14	71.72	71.76	72.17
Fat cuts, percent cold carcass weight	15.24	16.36	15.54	17.31
Total T.D.N. per lb. gain	2.36	2.90	2.33	2.52
T.D.N. per lb. gain after deducting for maintenance	1.79	2.03	1.51	1.78

lot 1 of this experiment. Their carcasses yielded a lower percent of fat. This suggests the lack of a direct relationship between natural fat deposition and any one of the other traits studied. The data further suggest that the various characters studied possess different relationships dependent on the gene complex of the animals under consideration.

Discussion

The results of this study are not strictly in accord with those of McMeekan and Hammond (1939); but on the other hand, it is not necessary that they should because the two studies were not conducted by identical procedures. McMeekan and Hammond started their pigs on restricted rations earlier in life than was done in this experiment. Furthermore, in their experiments the rations of lots 2 and 3 were controlled so they finished at the same age. In both their experiment and this experiment the group fed the restricted ration throughout yielded the highest proportion of lean meat. In this experiment, lots 2 and 3 gave essentially the same results, whereas in McMeekan and Hammond's the group full-fed for the first period and

restricted the second period yielded the better carcasses, especially in fullness of loin, but this may be due to the differences in procedure.

The results of the feeding experiment and the data taken from the Swine Breeding Project and used in this report are not in keeping with Dickerson's (1947) findings. Dickerson reported a strong association between the following characteristics: 1. Rapid increase in weight; 2. Rapid fat deposition; 3. Low feed requirements; 4. Poor suckling ability.

The methods of approaching the problem differed and this may in part, at least, explain the lack of agreement between the results of these two studies.

The results of this study show clearly that when allowance is made for differences in maintenance requirements the animals on restricted feed required less nutrients per unit of gain. This may be due to (1) increased efficiency of feed utilization by the animal on a restricted diet or (2) to less nutrients being required to produce lean meat than fat. In this case, the increased economy likely was affected by both factors. The data from the Swine Breeding Project show clearly that low feed requirements, rapid rate of gains and superior carcasses can be combined in the same genetic complex. It is true the illustrations used are all from crossbreds but the lines used in making the crosses, while not equal to the crosses, possess very satisfactory records of performance in these same respects.

In appraising the seemingly conflicting results between this experiment and those of McMeekan and Hammond on the one hand and those of Dickerson on the other, it should be kept in mind that each experiment was conducted with different genetic materials. If Dickerson's generalization is correct that there is a strong association between (1) high rate of gain; (2) low feed costs; (3) a fat carcass, and (4) poor milking qualities then a major task of the animal breeder is to break these associations. The data presented in this paper from the Swine Breeding Project show clearly that a high rate of gain, economy of feed utilization and a quality carcass can be combined. The data from the feeding experiment indicate that less nutrients are required to produce lean meat than fat. The evidence, however, is somewhat indirect as the more efficient utilization of feed by the animals on restricted rations may have been due in part or in whole to increased efficiency of the animals on light feed.

In appraising the results from different experiments bearing on this broad problem, it needs to be kept in mind that a slower rate of growth due to genetic causes is one thing and a slower rate of growth due to retarded growth may be very different. On the basis of this experiment and the results obtained by McMeekan and Hammond it appears that the most desirable results may be obtained when animals with an inherent capacity

for rapid growth are restricted somewhat in their growth rate at some period in their development. On the basis of both logic and Mc Meekan and Hammond's work we may conclude that the place for restricted feeding is during the finishing period. It would then appear logical that the ration during this period should be somewhat narrower than usually recommended.

Summary and Conclusions

Four lots of pigs were fed from shortly after weaning to market finish at different levels of feed intake, namely, HH, HL, LH, and LL as designated by Mc Meekan and Hammond.

The fourth group fed the restricted ration throughout the trial required somewhat less feed per 100 pounds of gain and decidedly less nutrients per unit of gain, when maintenance is taken into account.

The animals fed the restricted diet throughout produced the leanest carcasses.

From the above it is deducted that less nutrients are required to produce a pound of lean meat than a pound of fat. If this deduction is correct, then selection of breeding stock on the basis of economy of gains should be at least somewhat effective as a means of selecting animals that will yield a lean carcass.

The above deduction, however, is not in accord with Dickerson's findings. The differences in results do, however, support Blunn and Baker's suggestion that breed and line differences are indicated.

Taken as a whole, the study indicates that a task of the animal breeder is to search for desirable gene complexes. In cases where desirable gene complexes already in existence cannot be found, then his task is to break the old combinations, create new combinations, and from these new combinations sort out the more desirable ones for the development of superior lines or breeds.

It was not a part of the experimental design to contrast the efficiency of the outbred stock with the crosses of inbred lines. It is, however, worthy of note that the average total T.D.N. requirements for the four groups of crossbreds was only 78 percent of the requirements for the outbred population fed similar rations.

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ODOR AND TASTE TESTS OF PORK FROM ANIMALS SPRAYED WITH BENZENE HEXACHLORIDE[1]

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Idaho Agricultural Experiment Station

BENZENE hexachloride has proven to be a very effective insecticide and miticide when used against a number of pests of livestock and poultry.

Hixon and Muma (1947) state that the eggs and meat of poultry may be rendered inedible after birds or poultry houses are treated with this chemical for the control of chicken mites. These workers used a 5-percent concentration of wettable benzene hexachloride containing 5 percent of the gamma isomer and a benzene hexachloride water suspension containing 0.25 percent of the gamma isomer. In contrast, Harwood (1948) and Milby and Lawatsch (1948) reported that when oil emulsions containing 1.25–1.50 percent gamma isomer benzene hexachloride were used there was no effect on the taste of meat and eggs of poultry when applied for mite or louse control. It must be pointed out that these workers applied different solutions and concentrations of this chemical.

Since this station recommends the use of wettable benzene hexachloride for the control of hog lice and mange, tests were conducted to determine whether the meat or lard of hogs would become unpalatable after animals were sprayed with benzene hexachloride.

Procedures

Twelve pigs of the Duroc and Poland China breeds were used as experimental animals. They were selected shortly after weaning and all were infested with both mange and lice. The pigs were divided equally into two lots—three Durocs and three Poland Chinas being placed in each lot.

One group was thoroughly sprayed with a water suspension spray containing 20 pounds of 10 percent gamma isomer benzene hexachloride wettable powder in 100 gallons of water. The spray was applied at 500 pounds pressure. The other group was unsprayed and used as a check.

At two-week intervals an animal from each lot was butchered. Butchering did not start until two weeks after the spraying as it was felt that producers would not, under normal management, spray animals just before marketing or slaughtering. After slaughtering and chilling for 48 hours loin pork chops and fresh ham roasts were obtained from each animal. The meats were left

[1] Published with the approval of the Director of the Idaho Agricultural Experiment Station as Research Paper No. 284.

[2] Assistant Animal Husbandman, Assistant Entomologist, and Entomologist, respectively. Acknowledgment is made to Dr. Ella Woods, Home Economist for assistance with meat cooking.

TABLE 1. RESULTS OF ODOR AND TASTE TESTS TO INDICATE BENZENE HEXACHLORIDE IN COOKED PORK

Items studied			Odor and Flavor	Stage studied, and distribution of results of taste tests					
				2 weeks	4 weeks	6 weeks	8 weeks	10 weeks	12 weeks
				No. reporting	No. reporting	No. reporting	No. reporting	No. reporting	No. reporting
Chops	Sprayed animals	Odor	Pleasing	12	12	7	10	6	8
			Questionable	0	1	5	0	0	1
		Taste	Pleasing	12	12	7	5	6	7
			Off flavor	0	3	4	4	1	1
	Unsprayed animals	Odor	Pleasing	12	12	6	6	5	8
			Questionable	0	2	6	3	1	0
		Taste	Pleasing	12	10	6	6	4	7
			Off flavor	0	3	7	4	1	1
Roasts	Sprayed animals	Odor	Pleasing	12	10	12	7	6	7
			Questionable	0	4	0	2	0	1
		Taste	Pleasing	12	6	11	4	5	5
			Off flavor	0	7	1	6	2	4
	Unsprayed animals	Odor	Pleasing	12	11	10	7	6	7
			Questionable	0	3	1	2	0	0
		Taste	Pleasing	12	10	8	6	4	8
			Off flavor	0	2	3	3	2	0
Lard	Sprayed animals	Odor	Pleasing	12	13	11	10	6	8
			Questionable	0	0	0	0	0	0
		Taste	Pleasing	12	13	11	10	6	8
			Off flavor	0	0	0	0	0	0
	Unsprayed animals	Odor	Pleasing	12	13	11	10	6	8
			Questionable	0	0	0	0	0	0
		Taste	Pleasing	12	13	11	10	6	8
			Off flavor	0	0	0	0	0	0

unseasoned and cooked as recommended by the National Livestock and Meat Board (1945)—chops fried and roasts roasted until the internal temperatures were 185° F. After preparation the meats were cut into small pieces, given lot numbers and then sampled by members of the College of Agriculture staff. Their critical opinions concerning the taste and odor of each sample were recorded.

Lard was rendered from each animal slaughtered and used in pastry making. Each lard sample also underwent a taste and odor test.

The terms used to describe odor were: pleasing and questionable. Those used to describe taste were: pleasing and off flavor. The results of the taste and odor tests are tabulated in table 1.

Results and Discussion

As shown in the table the majority of the testers considered the samples pleasing in taste and odor throughout the test period. This indicates that there is no off odor or taste in the meat of swine treated with benzene hexachloride for the control of mange or lice when a water suspension spray is used two or more weeks before slaughter. As noted in the table some individuals reported questionable odors and off flavors; however, this can be attributed to the variations in the taste of individuals and the fact that the meat samples were unseasoned. Since completion of this experiment, Grummer, Bray and Bohstedt (1948) have reported that pork from recently sprayed animals had "off" taste and odor.

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RECORD OF PROCEEDINGS OF THE FORTIETH ANNUAL MEETING OF THE AMERICAN SOCIETY OF ANIMAL PRODUCTION

THE fortieth annual meeting of the American Society of Animal Production was held at the Hotel Sherman in Chicago on November 26 and 27, 1948, and a dinner for the honor guest was held at the Stockyard Inn on November 28. Abstracts of most of the papers presented were published in the November, 1948 issue of the JOURNAL OF ANIMAL SCIENCE, volume 7, pages 511–546.

PRESIDENT'S ADDRESS

PAUL GERLAUGH

President, American Society of Animal Production

THIS is the fortieth meeting of the American Society of Animal Production which has met annually with one exception. No meeting was held in 1945, due to situations resulting from the war. The Society is in excellent condition. The membership is increasing. This increase is due to several factors, though these factors all center around an increasing interest in the broad field of animal production.

The business manager and the secretary-treasurer are doing an excellent job of keeping slightly ahead of the rising costs. Most of you doubtless noticed the increase of fifty cents in the dues for the coming year. We are hopeful that further increases in dues will not be necessary, at least not in the near future. The Society is fast becoming too large for the present type of organization which has served it well in the past. Some changes in organization will be discussed at the business meeting tomorrow.

It is pleasing to note the continued interest and cooperation of the agronomists in our program. This interest we hope will not be confined to our pasture program as we have problems of mutual interest in the grain crops also.

Those who are interested in meats are showing us some important points to keep in mind in making production plans. They are also working on more efficient ways and means of processing and utilizing meats, one of the important products of animal production.

The field of our work as a Society in the entire livestock field is rightfully expanding. Our activities are interlocked with those of the American Dairy Science Association, the Poultry Science Association, the American Veterinary Medical Association, and the Livestock Sanitary Board in order to handle problems of a general nature and of mutual interest. At the present

time there is tangible evidence of these various organizations working together. This situation is very likely to expand. We are also represented on the Division of Biology and Agriculture of the National Research Council. This gives a general idea of the breadth of our organization.

During the year the office of Historian of the Society has been created and filled. More will be given about this development by the Committee on History of Livestock at the business meeting.

The JOURNAL OF ANIMAL SCIENCE is growing and doubtless is responsible for considerable increase in our membership. More papers are being received for publication, which means a larger JOURNAL and in turn a more expensive one. It costs more but is easily worth it. Some changes relative to the JOURNAL are in the making. The Editor, Ralph W. Phillips, was unable to attend the meeting of the Executive Committee yesterday. A meeting of the Committee is planned for this afternoon to consider matters relative to the JOURNAL. The results of this meeting will be given to you tomorrow.

The type of subject matter organization now being used for the various sections of our animal meeting seems to meet with fairly general approval. Some members do raise questions relative to the number of highly technical papers which appear on our program. It is hoped that the authors will, whenever possible, present their subject matter in terms that will show where their findings will fit into the applied sciences. It might be appropriate at this meeting to remind all who prepare papers that one of the fundamentals of teaching is to reach the unknown through the known.

May I take this opportunity to thank all who have helped your officers during the past year. The spirit and willingness to cooperate has been the finest possible. Committees and special representatives have given generously of their time and thought to the development of this year's program and to the solution of problems that arose during the year.

Secretary Briggs, Editor Phillips, and Business Manager Kammlade are the men whose load has been the heaviest. They have performed their work well and are to be commended.

It is entirely fitting to again recognize the assistance received from the National Livestock and Meat Board through Mr. Pollock and Mr. Biggar.

I should like to make a few comments with regard to the program to be presented at this opening session.

Animal breeding is certainly both an art and a science. Much discussion is heard as to which should predominate. The art of breeding is older and is responsible for much, probably most, of the tremendous improvement we see in our livestock today as compared with a century or half a century ago. Let no one feel that the livestock industry or the American Society of Animal Production is unaware of the tremendous contributions which the

breeders and their organizations have made and are continuing to make.

There are many who have the feeling that the rate of improvement has slowed down chiefly because the average excellence of our herds and flocks has been raised.

We cannot be content in our search for increased efficiency in breeding animals without exploring all the possibilities offered in both the arts and the sciences. There is great need for more facts to be used as guides in our thinking toward this end. Many wonder whether show ring and score card standards are as safe a guide as they once were thought to be.

Regardless of whether you individually are primarily interested in breeding as an art or as a science, we are certainly all together in wanting to get a more efficient livestock machine to turn our grass and hay and grain into meat and other livestock products. There is too much conversation on the part of our commercial livestock producers to ignore some of their suggestions and practices.

May the meeting this forenoon serve to draw a line around those who are interested in the art of breeding and those interested in the science of genetics rather than to draw the line between them.

Let us show tolerance, strive for facts, and perhaps inject more of the livestock philosophy of pretty is that pretty does.

The theme this morning is, "An Appraisal of the Present Day Situation Prospects for Improving Livestock Efficiency Through Breeding."

We are appreciative of the willingness of the various speakers to assist in the program. The theme is an appraisal of the present day situation and future prospects for improving livestock efficiency through breeding, and the subjects and speakers are:

Some Problems of Corn Belt Producers and Feeders of Beef Cattle, Hogs, and Sheep—Paul Hackett, Agricultural Lands, London, Ohio.

Problems of the Breeders of Purebred Herefords as I See Them—John Vanier, Brookville, Kansas.

Problems of the Breeders of Purebred Angus as I See Them.—Wayland Hopley, Atlantic, Iowa.

As Seen by the Breed Association Secretaries—Clinton K. Tomson, Chicago, Illinois.

What Genetics Can Offer—T. C. Byerly, U.S.D.A.

A SUMMARY OF THE MINUTES OF THE FORTIETH BUSINESS MEETING OF THE AMERICAN SOCIETY OF ANIMAL PRODUCTION

H. M. Briggs, *Secretary*
Oklahoma A. and M. College

THE meeting was called to order in the Louis XVI Room of the Hotel Sherman, Chicago, at 2:10 P.M., November 27, 1948, by President Paul Gerlaugh. One hundred twenty-five members attended the business meeting while 275 persons attended the luncheon which immediately preceded it and a total of 604 persons registered at the 1948 meetings.

Minutes of the previous meeting were not read as they had previously been published in the Journal of Animal Science, Vol. 7 (1): 137–144. The secretary read a report which showed an increase in membership during the year of 61 domestic and 5 foreign members; this brought total membership in the society to 885 persons in the United States and 60 in foreign countries. All members were sent two circular letters during the year. It was reported that Professor F. B. and Mrs. Morrison had deposited an additional $20,000 in an irrevocable trust fund administered by the Tompkins County Trust Company. This brings the total amount in that fund to $35,000 and the proceeds from the fund are to be used to provide additional Morrison Awards.

The Treasurer's report showed that during the year $1275.95 had been spent from the Morrison Award Fund while the account had no receipts; this left a balance of $3540.60 in that fund. There were receipts totaling $9221.13 received by the Society against an expenditure of $7098.49, or there was an increase of $2122.64 above operating expenses. This left a balance of $3769.51 in the general fund of the Society on October 31, 1948. In addition to the tangible cash balance, the Society had assets of $2112.00 in U. S. Bonds, Series F, and $7000 in U. S. Bonds. Series G. An auditing committee of Leslie Johnson, Chairman, F. N. Andrews and Jay L. Lush reported:

> We, the Auditing Committee, have this day audited the accounts of the American Society of Animal Production and find them to be correct as of October 31, 1948.

The Editor of the Journal of Animal Science, Dr. Ralph W. Phillips, summarized the Society's publication activities as follows:

> A total of 400 manuscripts had been submitted for consideration for publication in the Journal up to November 27, 1948. Of these, 325 were published in Volumes 1 to 7, inclusive. Of the remaining 75, 19 manuscripts were in press for the February 1949 issue, 10 others were edited and ready for the printer, 16 were in various stages of being edited, and a total of 30 manuscripts had been refused publication or had been withdrawn by the authors. Publication during 1948 included 55 manuscripts, the President's address and other Society proceedings

of the 1947 meeting, 99 abstracts of papers to be presented at the 1948 Annual Meeting of the Society, Subject and Author Indexes of Volume 7, and the usual News and Notes Section (a total of 113 items) in each of the four issues of the JOURNAL OF ANIMAL SCIENCE.

A summary of publication to date appears below:

Summary of Publication by Years

Year	*Manuscripts*	*Abstracts*
1942	40	80 (from 1941) 52 (for 1942)
1943	39	60
1944	48	72
1945	53	—
1946	41	92
1947	49	78
1948	55	99
Totals	325	533

The figure of 40 manuscripts for 1942 included the President's Address delivered at the 1941 meeting. In later years presidential addresses are included in the Society Proceedings. No meeting was held in 1945, hence no abstracts were published in that year. In addition to the items listed, an index of the Society Proceedings from 1908 to 1940 was published in 1946.

In view of the heavy load of publication being placed upon the JOURNAL, attempts to secure review papers on subjects of general interest have been kept to a minimum. Only one such paper has been published during the year. This appeared in the November issue, and was published without cost to the Society. One other review paper is nearing completion, and a second is now in preparation. It is hoped that in some cases, at least, funds can be found to finance the publishing of review papers that may be issued in the future.

The Editor announced that the terms of R. S. Glasscock. meats representative, and P. B. Pearson, nutrition representative on the Editorial Board would expire on December 31, 1948, and that the Executive Committee had appointed L. E. Kunkle and E. W. Crampton, respectively, to replace them.

The Editor also announced that, owing to pressure of other duties, it had become necessary for him to ask to be relieved of the editorial work, and that the Executive Committee had appointed Dr. L. E. Casida of the Genetics Department, University of Wisconsin, Madison, Wisconsin as Editor, effective about February 1, 1949. Thus, the current Editor will complete arrangements for the publication of the February issue, after which Dr. Casida will assume responsibility for all editorial matters, and the retiring Editor will continue to give such assistance as he can for the immediate future in the capacity of Editorial Adviser.

The Editor also emphasized the difficulties encountered in getting each issue, and particularly the November issue, in the mails on schedule, urged authors to return galley proofs promptly, and pointed out that in view of past experience, it would be necessary to ask that in future years, abstracts of papers to be presented at the annual meeting be in the hands of the Secretary by September 1.

Following Dr. Phillips' report and the announcement of his retirement as Editor, it was immediately moved, seconded, and passed that the members arise in appreciation of the eight years of faithful and efficient service rendered by the retiring Editor; the members arose and applauded. L. E. Casida of the University of Wisconsin was introduced as the new Editor.

The Business Manager of the JOURNAL OF ANIMAL SCIENCE, W. G. Kammlade, announced the decision of the Executive Committee to recombine the office of Business Manager and Secretary-Treasurer as they had been prior to 1948. He then read the following report for 1948.

The Society had available on November 1, 1948, the following numbers of complete volumes and single copies of the JOURNAL OF ANIMAL SCIENCE:

Volume	*Year*	*Complete volumes*	*Copies of numbers in addition to complete volumes*			
			No. 1	*No. 2*	*No. 3*	*No. 4*
1	1942	11	None	70	77	96
2	1943	83	44	24	None	12
3	1944	1	54	None	18	21
4	1945	None	None	None	None	None
5	1946	17	None	28	37	13
6	1947	13	9	None	14	22
7	1948	96	None	4	19	26

The complete sets are for sale by the Business Manager of the JOURNAL. Each complete volume is $3.50 and each single copy $1.00 in the United States. Prices elsewhere quoted on request.

The Society also has available for sale by the Business Manager of the JOURNAL the following copies of the Proceedings of the American Society of Animal Production. Prices vary somewhat with the year and the supply will be quoted on request.

Year	*No.*	*Year*	*No.*
1915–16	64	1931	80
1920	12	1932	34
1922	373	1933	52
1923	248	1934	53
1924	None	1935	54
1925–26	67	1936	12
1927	65	1937	None
1928	71	1938	9
1929	47	1939	24
1930	34	1940	82

President Gerlaugh announced the Ralston Purina Research Fellowship Award. He had previously appointed W. M. Beeson as the representative of the Society on the Award Committee.

A resolution which read as follows was presented by the Executive Committee:

The Executive Committee recommends that the American Society of Animal Production endorse the efforts of the National Research Council in advising the National Selective Service of the critical situation prevailing with respect to a deficit of scientists, and the time required in training them.

The resolution was unanimously passed and the secretary was asked to forward it to the National Research Council.

W. G. Kammlade read an amendment to the Constitution that was to have been voted upon at the 1947 meetings, which had been published in the JOURNAL OF ANIMAL SCIENCE (Vol. 6(3): 359). The amendment was adopted.

The Investigations Committee presented a letter which read:

The American Society of Animal Production commends the Association of Experiment Station Directors for the efforts of its members in encouraging and initiating regional conferences of research workers in particular fields of investigation. The Society is convinced that the exchange of results, ideas and interpretations at such conferences contributes greatly to the progress of research at the individual Experiment Stations represented. It suggests that the Association consider formulating a positive financial policy that will encourage and enable research workers to participate in such conferences in the manner most likely to be helpful in the conduct of their experimental work.

This letter was intended for transmittal to experiment station directors. It was moved, and carried, that the letter be sent. The Committee then gave the following report:

The present Committee gave early consideration to methods by which it could best serve the Society and the Livestock Industry. Many worthwhile suggestions were submitted by the individual members which included George K. Davis of Florida, G. E. Dickerson of Missouri, Max Kleiber of California and Paul B. Pearson of Texas, Upon reviewing their suggestions, it was decided to concentrate our efforts upon three activities.

The first pertained to breeding problems. Four committee members mentioned the need for better measurements and methods for improving livestock efficiency through breeding. Since this subject was selected for this year's Friday morning opening session, our committee felt that it could best serve by contributing to this program. Accordingly, all of our ideas and problems involving breeding and livestock efficiency were assembled and submitted to the President for his consideration in the Friday morning program.

The second committee activity resulted in the formulation of a letter addressed to the Society's Executive Committee for transmission to the Association of Experiment Station Directors. This letter recommended that the Association of Experiment Station Directors give consideration to formulating a *positive* financial policy towards encouraging conferences and meetings among individuals working on related problems in the various Experiment Stations.

The third activity of this committee was an educational feature concerning the use of radioactive isotopes in animal experimentation. Encouragment was not only given to the suggestion that a general paper be presented on the use of isotopes but also that a panel discussion be held.

This panel discussion was held at 7:00 P.M., November 27, in the Crystal Room of Hotel Sherman. The purpose of this panel discussion was to furnish information of the type most helpful to Society members who are either just beginning or who are "toying" with the idea of making use of isotopes in research related to farm livestock. Outstanding individuals within the Society, from the Atomic Energy Commission, and from the University of Chicago, took part in this panel discussion. It is hoped the meeting furnished a basis of understanding as to the application and potentialities of this new research tool.

The Committee on Instruction read their report as follows:

In accordance with the recommendation of the Committee on Instruction for the year 1947, your Committee for 1948 developed a program in which the sciences of genetics, physiology, biochemistry and nutrition have been presented. We suggest that the program next year be developed around the idea of applying the various sciences discussed in 1947 and 1948 to the problems of animal production.

The Extension Committee gave no formal report. Sectional chairman for next year's meeting is Grady Sellards.

The Membership Committee reported that all non-members that registered the previous year at the annual meetings had been contacted and that many had joined the Society. All heads of Animal Husbandry Departments have recently been contacted to review the membership standing of new personnel, and a similar contact is to be made with Dairy and Poultry Husbandry departmental heads.

The Committee on Pasture and Range Investigations suggested that their committee be continued and read the following statement:

Your committee has accepted the responsibility of revising and bringing up to date the "Preliminary Report on Pasture Investigations Technique." This report was prepared by a Joint Committee of the American Society of Agronomy, American Dairy Science Association, and the American Society of Animal Production, and was published in the Journal of Dairy Science in 1943. Your committee has made considerable progress in the revision of this report as has also the pasture committee of the American Dairy Science Association. The pasture committee of the American Society of Agronomy has only recently begun work on this project.

There is considerable work yet to be done. In order to maintain the continuity of this work we recommend to the Society that the present Pasture and Range Investigations Committee be given an opportunity to continue on this project for another year. We believe a completed report can be submitted at the next annual meeting of the Society.

The Committee on Information reported that 43 publications used stories covering the reports given at the 1947 meeting. The three features of last year's news releases were the presentation of the F. B. Morrison Award to W. L. Robison, the report presented relative to hog bruise losses which covered an intensive survey, and the presentation of the portrait of Dr. Hart to The Saddle and Sirloin Club.

The Committee on Necrology presented the names of members that had passed away during the year and the membership stood in silence as a memorium. The eulogies to their memory are published elsewhere in this JOURNAL.

The Committee on Monographs reported that the committee did not feel such publications should be undertaken by the Society.

The Committee to Amend the Constitution announced they had no recommendations.

The Committee on Membership in the Institute of Biological Sciences gave a lengthy report which the Secretary was instructed to send to the National Research Council. The report may be briefly summarized as follows: Each member of the committee, separately and independently, gave serious consideration to the problem assigned. Each had an opportunity to study the file on the AIBS loaned by Dr. Ralph W. Phillips. Each came to the same general conclusions and the committee recommended that the American Society of Animal Production not affiliate with the American Institute of Biological Sciences as a member society. The committee's recommendation was accepted.

The Resolutions Committee presented the following resolutions which were adopted:

1. The Society is deeply indebted to Dr. Ralph W. Phillips, who has served very capably for more than seven years as editor of the JOURNAL OF ANIMAL SCIENCE since the first issue was published in February, 1942. The high standard maintained by the JOURNAL has resulted in its being highly regarded among scientific journals.

2. The Society wishes to express its thanks to John Morrell and Company for reprinting summaries of the papers presented at the annual meeting.

3. The Society wishes to express its appreciation, to the George Banta Publishing Company for the excellent service it has rendered in publishing the JOURNAL OF ANIMAL SCIENCE, and particularly for the special efforts the company made in getting the November issue printed promptly and distributed in advance of the Society's annual meeting.

4. The Society wishes to express its appreciation to the Sherman Hotel for its excellent cooperation in furnishing the facilities necessary for the meetings of the Society. It is to be remembered that the Society has met at the Sherman Hotel, with the exception of one year, since the year 1919.

5. Appreciation is hereby expressed to the National Livestock and Meat Board, Director R. C. Pollock and staff, for their efforts in handling publicity pertaining to this meeting and its activities. The support of the Board in research work on meats has been of profound significance.

6. This Society wishes to express its appreciation and thanks to Professor and Mrs. F. B. Morrison for their generosity in establishing the fund for the continuation of the annual Morrison Award in recognition of outstanding work in animal production.

There was no report from the Society representative to the Inter-Association Council. H. C. McPhee gave a verbal progress report of the Inter-Society Committee on Science Foundation Legislation.

H. W. Marston read the following report concerning the activities of the Division of Biology and Agriculture of the National Research Council:

Dr. Griggs retired as Chairman of the Committee on Biology and Agriculture on July 1, 1947. Dr. John A. Nicholas, Sterling Professor of Biology at Yale University, was appointed Chairman of the Committee on February 22, 1948.

The Agricultural Board, a group of outstanding agricultural leaders, which is sponsored by the Committee on Biology and Agriculture, reported that its Committee on Feed Composition had been extremely successful during the year in obtaining industrial and foundation

support. The Food and Nutrition Board reported on the drafting of a comprehensive research project to determine the effect of regulatory measures and trade practices upon the quality of milk.

The Division Committee on Fellowships recommended and the National Research Council approved the following fellowships:

1. Thomas Burnett, for research at the University of California on the population of the greenhouse whitefly and its parasites.
2. Sol Kramer, for research at the University of Cambridge on the physiology of the hairy rose beetle.
3. Iben Browning, for research at the University of Pennsylvania on the physiology of the mechanics of the genetics apparatus.

The Fellowship Board reaffirmed that the fellowships were awarded to encourage the habit of research in those recently receiving Ph.D. degrees.

The applications of the following organizations were approved for representation on the Committee of Biology and Agriculture.

1. American Association of Anatomists.
2. Eastern North American Region of the Biometric Society.

The application of the Torrey Botanical Society was tabled.

A series of five new fellowship boards have been created to advise and administer the new Atomic Energy Commission fellowships: one for pre-doctoral fellowships in the physical sciences; one for post-doctoral fellowships in the biological sciences; and one for pre- and one for postdoctoral fellowships in biology and agriculture; and one for post-doctoral fellowships in the field of medicine.

Some time was given to a discussion of the Fulbright Bill (Public Law 584) which authorizes the Department of State to use a portion of the foreign currencies resulting from the sale of surplus property abroad for educational activities with foreign countries.

Fred F. McKenzie gave his report as the representative on the American Association for Advancement of Science Council as follows:

Your representative on the AAAS Council reports that he has spent some time in learning the duties of this office, its responsibilities and its opportunities. The AAAS is a federation of scientific societies in the United States and Canada, which is striving to increase public understanding of the importance of the methods of science in human progress.

Dr. McKenzie expressed the view that in peacetime the Society would wish to limit its activity in the AAAS to individual participation rather than to hold meetings as a section at an AAAS convention.

Ralph W. Phillips, the Society's representative to maintain contact with the development of an international animal husbandry association, presented the following report:

An international meeting on Animal Husbandry was held in Zurich, Switzerland, on October 8 and 9, 1947. Among other things, that meeting considered the formation of an international animal husbandry association and suggested that continental societies be formed which might band together into a world federation. The first step in carrying out the recommendations of that meeting was the formation of a Committee to consider the development of a European association. That Committee held its meeting in Milan, Italy, during the period June 28 to July 1, 1948, inclusive, with representatives of eight countries present as follows:

F. Lievens, Belgium; J. Jesperson, Denmark; A. M. Leroy, France; Z. Csukas, Hungary; Ugo Sola, Italy; C. J. M. Rijssenbeek, Netherlands; W. Engeler, Switzerland; and J. L. Mason, United Kingdom. The meeting was convened by the Food and Agriculture Organization of the United Nations, in accordance with a request of the Zurich meeting, and Ralph W. Phillips and I. Moskovits of FAO were in attendance. It was recognized that the Committee was competent to deal only with the problems of organizing a European association and that consideration of the organization of an international association should be left until a later date. The Committee drew up draft statutes for the proposed European Association for Animal Production, setting forth its aims as follows: (a) to encourage the exchange of views between specialists in all branches of animal production both in the practical and in the scientific field; (b) to co-ordinate in Europe work in all fields of animal production; (c) to arrange for the organization of international congresses, conferences and any other appropriate undertakings in the field of animal production, in collaboration as far as possible with specialized international associations. To this end it can set up special committees to carry out the preparatory work necessary for the study of the problems concerned; (d) to set up a permanent secretariat, provided with adequate resources. Its chief function is to implement the decisions of the Association and to establish archives for documents and other information of interest to Members; (e) to publish in the appropriate form and at the opportune moment all work which is of interest to the Members of the Association and which can contribute to the realization of its aims; and (f) to make an effective contribution to all work of general interest relating to animal production

The draft statutes also provide that the membership shall consist of national organizations which best represent the interests of animal production in the scientific, practical and administrative fields and only one such national organization is to be admitted to membership for any one country. The detailed draft statutes will be considered for adoption at an organization meeting which is scheduled to be held in Paris in October, 1949. This meeting will be held in conjunction with an International Congress on Animal Production which is being sponsored by the French Government. It was suggested by the Committee which met in Milan that, at the time of the Paris Congress, consideration might be given to the possibility of forming an international association.

It was agreed that no formal action should be taken at this time, but rather that a decision with regard to cooperating in setting up an international association should be left until the proposed European association is well established.

The Nominating Committee placed the name of W. G. Kammlade for president and the names of P. S. Shearer and F. L. Bentley for vice-president before the house. There were no further nominations from the floor and W. G. Kammlade was elected president and P. S. Shearer vice-president in the ensuing election.

The meeting was adjourned at 4:08 P.M.

MEMORIALS

SAMUEL IRVIN BECHDEL

Professor emeritus Samuel I. Bechdel died at State College, Pennsylvania, on September 13, 1948, at the age of 62 years, after a long period of failing health. Dr. Bechdel's entire life was spent in dairy production work. He was born and reared on a dairy farm in central Pennsylvania. Dr. Bechdel graduated from the Pennsylvania State College in 1911, received the M.S. degree from the Pennsylvania State College in 1916, and the Ph.D. degree from the University of Minnesota in 1925. After graduation, he spent two years with the Division of Dairy Industry, U.S.D.A., returning to the Pennsylvania State College in 1913, and served the College and Experiment Station continuously until his retirement on January 31, 1946.

Dr. Bechdel was responsible for the development of an extensive dairy production research program at the Pennsylvania State College. These investigations were mostly along nutritional lines. He made extensive studies with various kinds of silage and pasture crops. He also did a large amount of work with vitamins, demonstrating the importance and need of vitamin A for milk production and for growing calves. He was one of the first investigators to show that vitamin B complex was synthesized in the digestive tract of ruminants and the importance of vitamin C for growing calves, and he was the author of numerous bulletins and papers on the several phases of his work with dairy cattle.

GEORGE ARTHUR BELL

George Arthur Bell was born May 14, 1879 in Rome, New York and died in Davis, California, June 1, 1948. He received the B.S.A. degree from Cornell University in 1904 and taught in the animal husbandry department of that institution for a time. In 1905 he joined the animal husbandry staff of the U.S.D.A. where he served until 1920. During this period of service he held the rank of Assistant Animal Husbandman, and Senior Animal Husbandman. From 1920 to 1935 he served as consultant and specialist on horse breeding with the War Department. During the years of 1926 and 1927 Professor Bell did graduate work at the University of California. In 1937 he was appointed associate in animal husbandry at that institution, where he was stationed at the W. K. Kellogg Institute of Animal Husbandry at Pomona. In 1939 he was transferred to the College of Agriculture, University of California at Davis where he remained until his retirement July 1, 1943. Professor Bell was the author of U.S.D.A. Farmers Bulletin No. 619, "Breeds of Draft Horses," and Farmers Bulletin No. 1030, "Feeding Horses," and many popular and scientific articles on all phases of the horse industry. He was a member of the National Press Club and the University Club both, of Washington, D. C.; the faculty club of Davis and the Del Paso Club of Sacramento. He was an honorary member of the Zeta Xi fraternity, and an active member of the National Horseman's Association. Professor Bell was active in civic life even after his retirement. He was director of the U.S.O. in Davis during World War II. He was later elected City Judge and Justice of the Peace in Davis, and served in this capacity for two years.

Surviving Professor Bell are his wife, Mrs. Lavinia Pryor Bell; a stepdaughter, Mrs. Mary Pryor Black of Seattle; a sister, Mrs. Edith C. Pritchard of Utica, New York; and two brothers, Frank S. Bell of Rose, New York, and Professor Floyd Bell of Manhattan, Kansas.

LEON JACOB COLE

L. J. Cole was born June 1, 1877 at Allegany, New York and died February 17, 1948 at his home in Madison, Wisconsin. On graduation from high school in Grand Rapids, Michigan, he studied at Michigan State College. He later entered the University of Michigan where he graduated in 1901 specializing in zoology and botany. After a year as graduate assistant in zoology at Michigan, he entered Harvard University where he received his Ph.D. degree in 1906. Dr. Cole's early interest in plants and animals shaped his life from boyhood, resulting in his becoming a pioneer in the field of genetics and an outstanding national leader in biology. While still an undergraduate at the University of Michigan he was selected to join the Harriman Alaskan Expedition of 1899. Other broadening experiences included a summer at the Ber-

muda biological station in 1903, a zoological expedition to Yucatan in 1904, a summer at the Tortugas station in the Gulf of Mexico in 1906, and other summers between 1901 and 1906 at Woods Hole, Massachusetts. Dr. Cole held a number of positions before joining the staff at the University of Wisconsin. He spent a year (1906–7) at the Rhode Island Experiment Station in the division of animal breeding and pathology. In 1907 he became instructor in zoology at the Sheffield Scientific School, Yale University. In 1910 he went to the University of Wisconsin, and except for one year's leave in 1923 when he served as Chief of the Animal Husbandry Division, Bureau of Animal Industry, U.S.D.A., and the summer of 1930 spent as Research Professor at Western Reserve University, he was at the University of Wisconsin until his retirement in June 1947. Under Dr. Cole's leadership, the first department of genetics in the United States was founded at the University of Wisconsin in 1910. The department attracted graduate students from all over the world and became a mecca for scholars of genetics and animal breeding.

In addition to performing the duties of administration, research and teaching in the department, Dr. Cole took an active part in many learned and scientific societies. The American Society of Animal Production presented his portrait to the Saddle and Sirloin Club in 1939. In 1945 he was awarded the honorary degree of doctor of science by Michigan State College.

Dr. Cole is survived by Mrs. Cole, formerly Miss Margaret Belcher Goodenow, and their two children, Mrs. Margaret Husting of Wisconsin Rapids, Wisconsin, and Edward G. Cole of Mankato, Minnesota.

JOHN MARCUS EVVARD

Death came on July 30, 1948 to Dr. John M. Evvard at the Good Samaritan Hospital in Phoenix, Arizona. He had been confined to his home because of bad health for the last three years but he had been critically ill for only a week. Born November 6, 1884 at Saunemin, Illinois, he was graduated from the University of Illinois with a Bachelor of Science degree in 1907. He received the degree of Master of Science in Agriculture from the University of Missouri in 1909 and in 1927 was awarded the degree of Doctor of Philosophy by the University of Arizona. Before joining the Iowa State College faculty in 1911 he served as assistant to the Dean and Director of the Missouri Agricultural College and the Missouri Agricultural Experiment Station. Dr. Evvard was in charge of the animal husbandry section and chief of swine, beef cattle and sheep production at the Iowa Agricultural Experiment Station from 1911 to 1930. During this period he was a leader in the field of applied animal nutrition. He was known personally to thousands through his research and writings for farm papers. Evvard was a member of the Farmers Live Stock Marketing Committee of 15; U. S. Live Stock Industry Committee in 1917, and chairman of the advisory committee on swine, Food Administration in 1917 and 1918. He was vice president of the American Society of Animal Production in 1916 and president in 1918.

Ill health forced Dr. Evvard to leave Iowa, and he moved to Phoenix, Arizona in 1933. He served as a consultant for several large companies. He was professor and head of the Department of Agriculture at the Arizona State College at Tempe from 1935 to 1937. Dr. Evvard was a member of Alpha Zeta and Gamma Sigma Delta, honorary agricultural fraternities, Sigma Xi, American Association for the Advancement of Science and a fellow of the Iowa Academy of Science.

EDWIN A. TROWBRIDGE

E. A. Trowbridge was born at Mondovi, Wisconsin, April 27, 1885 and died in Columbia, Missouri June 7, 1948. On graduation from the University of Wisconsin in 1906, Dean Trowbridge went to the University of Missouri as an instructor in Animal Husbandry. He became professor of Animal Husbandry in 1909 and was made head of the department in 1910. In 1945 he was made dean of the College of Agriculture and director of the experiment station. He served the University and the people of Missouri for forty-two years. Dean Trowbridge was widely recognized as an authority in the field of Animal Husbandry and was in great demand throughout the United States as a judge at major horse and beef cattle shows. In

1942 he was called to Argentina to judge Shorthorn and Aberdeen-Angus cattle at the Palermo Show. "Chief," as he was affectionately known to his many friends, students, and associates, endeared himself to all who knew him by his kindness, fair dealings, loyalty, high ideals, and his devotion to duty. To the thousands, young and old, whom he influenced, he was always the ardent advocate of livestock farming as a noble and satisfying way of life.

Dean Trowbridge was author or co-author of many publications of the Missouri Agricultural Experiment Station as well as a contributor to scientific journals and farm papers. He served as president of the American Society of Animal Production in 1924. In 1941 the Society honored him by hanging his portrait in the Saddle and Sirloin Club in Chicago. He was a member of many scientific and professional societies and was always active in church and civic affairs. He was married in Wisconsin to Miss Alice Goddard who, with two sons, Edwin A., Jr. and Leigh M., survive him.

CHAIRMEN OF COMMITTEES, PROGRAM CHAIRMEN AND SPECIAL REPRESENTATIVES FOR 1949

Standing Committees

Committee on Investigation ..... G. E. Dickerson
Committee on Instruction ..... E. H. Hughes
Committee on Extension ..... Grady Sellards
Committee on Membership ..... P. S. Shearer

Special Committees

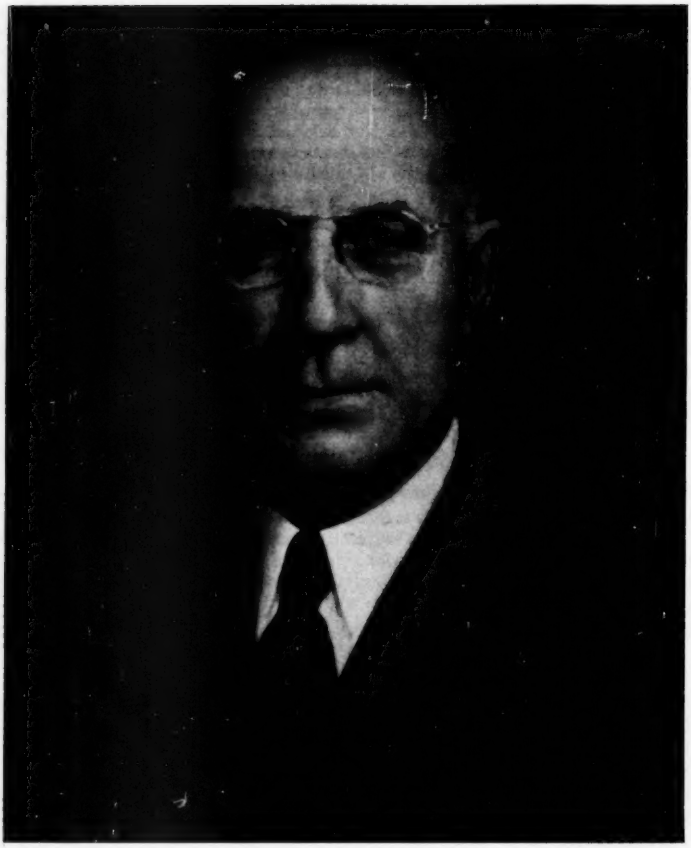
Committee on Pasture and Range Investigations ..... G. O. Mott
Committee on History of Livestock ..... C. W. Gay
Committee on Information ..... R. C. Pollock
Committee on Necrology ..... M. E. Ensminger
Nominating Committee ..... W. A. Craft
Committee on the Morrison Award ..... P. S. Shearer
Committee on American Feed Manufacturers' Award in Nutrition ..... A. D. Weber

Program Chairmen

Breeding and Genetics Section ..... E. J. Warwick
Extension Section ..... Grady Sellards
Meats Section ..... K. F. Warner
Nutrition Section ..... B. H. Schneider
Pasture and Range Section ..... O. Burr Ross
Physiology Section ..... R. W. Bratten
Teaching Section ..... E. H. Hughes

Special Representatives

Inter-Association Council ..... E. A. Livesay
Science Legislation ..... H. C. McPhee
Council of American Association for Advancement of Science ..... F. F. McKenzie
Division of Biology and Agriculture, National Research Council ..... H. W. Marston
Proposed International Animal Husbandry Association ..... R. W. Phillips



WALTER H. PETERS

Reproduction of a portrait presented to the Saddle and Sirloin Club in Chicago by the American Society of Animal Production on November 28, 1948. Walter H. Peters was the Honor Guest of the Society during its annual meeting which was being held at that time.

WALTER H. PETERS

Honor Guest—1948

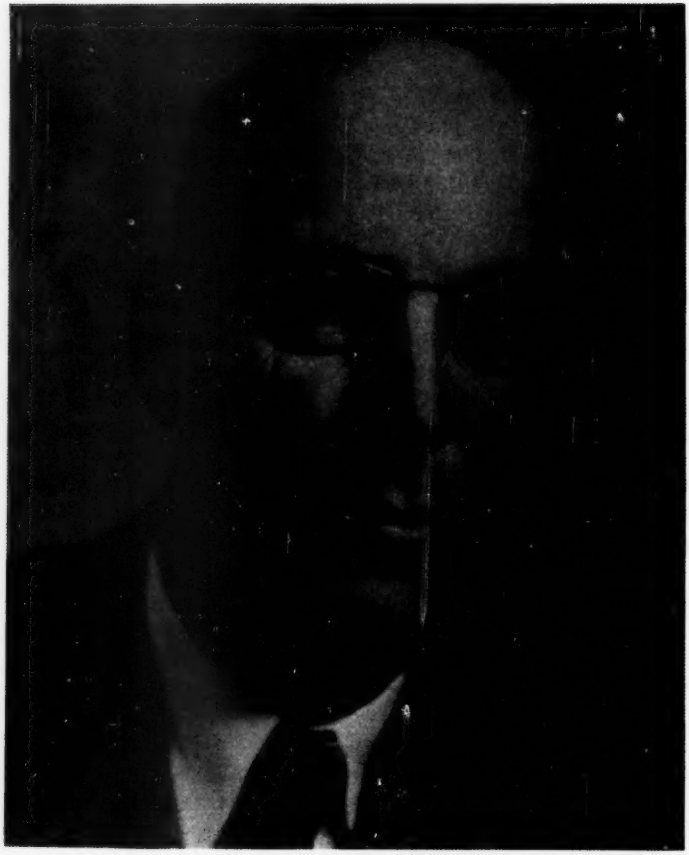
Walter H. Peters was born July 9, 1885 on a farm near Keokuk, Iowa and received his early education in a one-room country school. After graduating from the Keokuk High School with a scholastic rank of second in a class of 60, he headed toward the Iowa State College to continue his education. While a student at Ames, he participated in many extra-curricular activities, holding numerous offices such as class president, president of the Agricultural Club and business manager of the class annual. The position of editor of the college paper, the "Iowa State College Student," was held during his senior year.

Walter Peters was a member of both the college corn judging team and the livestock judging team, winning first in the placing of horses. Following graduation in 1908, he filled the position of instructor in Animal Husbandry at the Iowa State College for three months before locating at the Manitoba Agricultural College for a period of nearly six years. As the only member of the staff in Animal, Poultry and Dairy Husbandry for the first two years, he received a broad education by teaching classes in all three fields.

During his sojourn in Manitoba, Professor Peters married his college sweetheart, Millie Gillette. A son, a daughter and three grand-children compose a happy and congenial family.

Before moving to the University of Minnesota in the fall of 1918, Walter Peters served as Head of the Animal Husbandry Section of the North Dakota Extension Service for a period of four years. His present position of Chief of the Division of Animal Husbandry at the University of Minnesota dates from September 1, 1921. He has been active in expanding the program of livestock improvement at both the Central Experiment Station and the five sub-stations. Under his direction, the experimental program with livestock has been greatly enlarged and given wide publicity. He is the author of a popular text and reference book, "Livestock Production" and co-author of "Raising Livestock." The first of these texts was used by the United States Armed Forces Institute and was translated into Spanish. Besides writing many bulletins, Peters has served as livestock editor of "The Farmer" and associated publications for a period of 32 years.

Since 1920 he has attended most of the meetings of the American Society of Animal Production and served as its president in 1941, when the preparatory work of publishing the JOURNAL OF ANIMAL SCIENCE was begun.



LAURENCE M. WINTERS

Laurence M. Winters was awarded the third Morrison Award which was presented to him during the 40th annual meeting of the American Society of Animal Production in Chicago on November 27, 1948.

THE MORRISON AWARD

1948

Dr. Laurence M. Winters, selected by the Morrison Award Committee of the American Society of Animal Production as the 1948 recipient of the Morrison Award, is a foremost research worker in the field of animal breeding. He is also a physiologist of note and a practical animal husbandman. Since 1928, he has been a member of the animal husbandry staff of the University of Minnesota in charge of the section of animal breeding. Attention of associates and contemporary workers was first attracted to Dr. Winters by the publication of the book, "Animal Breeding," in 1930. This book attained wide acceptance as a text for undergraduate courses in animal breeding in agricultural colleges. The fourth revision was published in 1948.

As a research worker in the field of Animal Breeding, Dr. Winters has demonstrated unusual originality, vision, thoroughness, untiring energy, and promptness in reporting the results of experimental work. Outstanding among the many research projects he has directed are the studies in crossing breeds of swine, studies in the physiology of reproduction and prenatal development of farm animals, studies in techniques in artificial insemination of cattle, and studies in methods of breeding for the improvement of farm animals. Results secured from his research work have attracted world-wide attention to him as an authority in the field of animal breeding and genetics. The outstanding accomplishments of Dr. Winters in animal husbandry research are his research on improvement within the Poland China breed of swine, and the formation of the two new breeds of swine, the Minnesota No. 1 and the Minnesota No. 2. Beginning with a crossbred foundation, each of the two new breeds was brought to a high degree of uniformity within a period of ten years' time. This was accomplished by applying genetic principles in practical animal breeding to the fullest extent possible. This work establishes Dr. Winters as one of the leading pioneers in the application of genetic principles to the improvement of farm animals.

Personal attributes, background of training, and experience in practical livestock production give Dr. Winters ability as a teacher, lecturer, and writer. He has excelled in the field of teaching as well as in the field of research. His ability as a teacher combined with his program of research attracted many students to the Graduate School of the University of Minnesota for graduate study under his advisorship. Keeping in mind the man raising livestock on the farm as the ultimate agent in putting results of constructive research into practice, Dr. Winters has given generously of his time in responding to invitations to speak at meetings of livestock breeders and other farmer groups.

EARL W. CRAMPTON

Earl W. Crampton was awarded the first American Feed Manufacturers Association Award which was presented to him during the 40th annual meeting of the American Society of Animal Production in Chicago on November 27, 1948.

THE AMERICAN FEED MANUFACTURERS ASSOCIATION AWARD

1948

Dr. Earl Wilcox Crampton was born in Middletown, Connecticut, received his Bachelor's Degree from Connecticut Agricultural College, his Master's Degree from Iowa State College and his Doctorate from Cornell University. He has been on the staff of MacDonald College, McGill University, Quebec continuously since 1922, and received his professorship in 1941. He was selected for this award by a committee of the American Society of Animal Production. His productivity and leadership in the field of animal nutrition is attested to by 76 publications during the years 1926 to 1948 dealing particularly with the fields of swine nutrition, nutritive value of feeds and of pastures, chemical methods of assessing feeding value and experimental design for feeding experiments. His work on evaluation of feeds and nutrient requirements of swine have influenced practice throughout the United States and Canada. Papers during the period 1946–47 contributed significantly to knowledge of vitamin D requirements of swine, effects of vitamin B entities, protein level, and proportion of animal protein as supplements to barley and wheat in bacon hog rations. A paper on fineness of grinding of oats as affecting utilization by swine was of direct practical value. These papers gave insight into small nutritional effects related to "building a product" to strict specifications. Use of ferric oxide as a feces marker was shown to be advantageous for shorter collection periods and with variable feed intake in swine digestion trials.

The twenty-seventh of a series of studies on pasture combined the methods of plant histology with those of the chemist in the investigation of the mode of lignin deposition and its effects on digestibility of forage. This represents a new approach to the problems of changing nutritional value as plants grow and mature. This series of publications has contributed significantly to more accurate appraisal of nutrition value through modification of analysis of the carbohydrate fractions.

In addition to subject matter contributions, Dr. Crampton's investigations serve as models of experimental design, affording clarity of analysis, presentation results and economy in science. From a meager beginning, he has built up a Department of Nutrition at MacDonald College that now embraces both animal and human fields. Dr. Crampton has served with distinction in the American Society of Animal Production, the Canadian Society of Technical Agriculture, the Canadian National Swine Committee, the National

Feed Committee, the Provincial Feed Board and Canadian Council of Nutrition. He is a member of the Board of Editors of the Journal of Nutrition, the Animal Nutrition Committee of the U. S. National Research Council and its subcommittee on Recommended Nutrient Allowances for Swine.

NEWS AND NOTES

Effective February 1, 1949, all correspondence regarding manuscripts, news and notes, and other items normally handled by the Editor of the JOURNAL OF ANIMAL SCIENCE should be addressed to:

Dr. L. E. Casida
Department of Genetics
University of Wisconsin
Madison, Wisconsin

Dr. Casida, the newly appointed Editor, replaces Dr. Ralph W. Phillips, who asked to be released from the post, after serving as chairman of the Editorial Board during 1941 when the JOURNAL was being organized, and as Chairman and Editor from 1942 through January 1949.

The Western Section of the American Society of Animal Production will holds its next annual meeting on January 27, 28 and 29, 1949. This will be a joint meeting participated in by the Western Section of the American Society of Animal Production and the Western Division of the American Dairy Science Association. The State College of Washington at Pullman, and the University of Idaho at Moscow, will act as joint hosts at the meeting. Professor R. F. Miller of the University of California at Davis, is President of the Western Section. Professor W. P. Lehrer, Jr., of the University of Idaho, is Secretary.

The Ralston Purina Company has announced seven Research Fellowships which will be awarded on an annual basis and the recipients may receive an award for as much as three years. Awards will be in the fields of nutrition and physiology research as applied to dairy, poultry and animal husbandry; and research in transmissible diseases of livestock and poultry. Individuals qualified for graduate study in any Land-Grant Agricultural College and approved Veterinary Colleges are eligible. Fellowships are for $1,440 annually and application blanks may be obtained from Ralston Purina Research Awards Committee, c/o Mr. J. D. Sykes, Ralston Purina Company, St. Louis, Missouri. Applications must be on file by March 1 of the year for which the award is to be made.

Sam Nordfeldt, of the Royal Agricultural College of Sweden at Uppsala, has been appointed Animal Husbandman at the Agricultural Experiment Station of the University of Hawaii, effective March 1, 1949. Dr. Nordfeldt received his doctorate in 1938 at the University of Wisconsin majoring in Biochemistry with a minor in Medical Physiology.

Kenneth K. Otagaki, who was Junior Animal Husbandman at the Hawaii Agricultural Experiment Station, has been awarded a fellowship by the McInerney Foundation of Honolulu and is now doing graduate work toward the Ph.D. degree at the University of California. He received his M.S. degree from Iowa State College in 1946.

Charles B. Webster, who received his B.S. degree from the University of Hawaii in 1947, is now Assistant-in-Animal Husbandry at the University of Hawaii.

H. M. Briggs of the Animal Husbandry Department at Oklahoma A & M College, Stillwater, Oklahoma, has been appointed Associate Dean of Agriculture and Associate Director of the Experiment Station at that Institution. The appointment was effective February 1 and Dr. Briggs will continue to do some work in the Animal Husbandry Department during the current semester.

Russell Coleman, Director of the Mississippi Agriculture Experiment Station, resigned October 31, 1948, to become president of the National Fertilizer Association.

Fred W. Wilson, head of the Animal Husbandry Department, University of Nevada, and associated with that institution since 1915, died suddenly from a heart attack on December 7. E. W. Sheets was appointed to fill the vacancy early in January.

Ellis McFarland, Secretary of the Percheron Society of America and also of the National Society of Purebred Record Associations, died October 26 from a heart attack, at the age of 59.

S. S. Wheeler, of the Colorado A & M College is now serving as Vice-Director of the Agricultural Experiment Station in addition to his duties as head of the Animal Husbandry Department.

Henry P. Holzman was appointed Associate Extension Animal Husbandman at South Dakota State College, effective July 1, 1948.

Ralph McCall, formerly of the Animal Husbandry staffs at Montana State College and the University of Arizona, is now manager of a Hereford ranch at Vaughn, Montana.

Rollo E. Singleton has been selected as Secretary of the American Corriedale Breeders' Assn to succeed Frederic S. Hultz, resigned, and the headquarters of the Association have been moved to Columbia, Missouri.

Waldo S. Rice, for many years a member of the animal husbandry staff, University of Georgia, and more recently field man for a breed association, is now manager of Modena Plantation, Savannah, Georgia.

Jay Myers has been appointed instructor and research assistant in wool at the University of Wyoming to succeed Donald Johnston who went with the Wool Division of the U.S.D.A.

Marshall C. Heck, who has been in commercial work, returned to the University of Arkansas January 1, where he will handle swine and meat work in the Animal Husbandry Department.

B. T. Whittle has been appointed to succeed Ural Bee, resigned, on the Animal Husbandry Extension staff at the University of Maryland.

A. E. Cullison has been appointed head of the Animal Husbandry Department at the University of Georgia.

In recognition of the services rendered the livestock industry by J. A. Hill, Dean of Agriculture at the University of Wyoming, the Warren Livestock Company of Cheyenne has set up a scholarship fund of $5000 at the University of Wyoming. Interest from the fund will be awarded annually to a third year student on the basis of outstanding work and campus citizenship.

The West Virginia University Agriculture Experiment Station has been awarded a grant-in-aid of $4000 by Swift and Company in support of a project on the digestibility and consumption of feeding stuffs by farm animals. This is the sixth consecutive year that the project has been given support by Swift and Company. Research is being conducted under the direction of Burch H. Schneider.

The fourth edition of "Principles of Veterinary Science" by F. B. Hadley was published in January 1949, by W. B. Saunders Company, Philadelphia and London. The book has been completely revised, giving less emphasis to horses and more to dairy cattle. This text is in-

tended to meet the needs of the present-day students of the animal sciences and also to give pre-veterinary students an insight into the opportunities which veterinary medicine offers as a profession.

W. H. Riddell has been appointed Head of the Animal and Dairy Husbandry Department, University of Vermont.

P. B. Pearson has accepted a position as Assistant Chief of the Biology Section of the Atomic Energy Commission. He is on leave from the Agricultural and Mechanical College of Texas.

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